AGE DIFFERENCES IN THE SYLLABLE FREQUENCY EFFECT ON SPEECH PRODUCTION: COMPARISONS BETWEEN TIP-OF-THE-TONGUE STATES AND PICTURE NAMING

By

MEAGAN T. FARRELL

A THESIS PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE

UNIVERSITY OF FLORIDA

2009

To my parents, for their unwavering love and encouragement, and to my advisor, Lise Abrams, for her invaluable insight throughout this process.

ACKNOWLEDGMENTS

I thank Meredith Shafto for her assistance in procuring the syllable frequency norms for the stimuli used in these experiments, without which this project would not have been possible.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT OF THESIS PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE

AGE DIFFERENCES IN THE SYLLABLE FREQUENCY EFFECT ON SPEECH PRODUCTION: COMPARISONS BETWEEN TIP-OF-THE-TONGUE STATES AND PICTURE NAMING

By

Meagan T. Farrell

December 2009

Chair: Lise Abrams
Major: Psychology

Phonological retrieval is one aspect of language processing that is susceptible to age-related decline, although little is known about the interaction between aging and the particular phonological qualities of words. Syllable frequency, or the occurrence of specific syllables within the words of a language, has been shown to facilitate production in some languages, but has yielded inconsistent results in English, and has never been examined in older adults. The current project investigated the influence of first-syllable frequency on tip-of-the tongue (TOT) incidence and resolution, picture naming, and picture-word interference in young, young-old, and old-old adults. For TOT incidence, high-frequency first syllable targets elicited fewer TOT states relative to low-frequency for both groups of older adults, but not for young adults. Picture naming was also facilitated by high-frequency syllables, but only for old-old adults. In contrast, when a prime word with the same first syllable as the target was presented, i.e. for TOT resolution and picture-word interference, having a large syllable cohort was detrimental for production, with higher resolution rates and faster naming latencies for low-frequency first syllables. These findings support speech production models that allow for

bidirectional activation between semantic, lexical, and phonological forms of words. Furthermore, the age-specific effects of syllable frequency provide insight into the progression of age-linked changes to phonological processes.

CHAPTER 1
INTRODUCTION

Although the production of speech seems to occur effortlessly and immediately, the act of producing even a single word is actually quite complex, consisting of several independent, though interconnected stages. Models of speech production propose a multi-staged process that begins with the activation of abstract conceptual information to be expressed and ends with the articulation of the selected word (Dell, 1986; Levelt, Roelofs, & Meyer, 1999; MacKay, 1987). Although the various models somewhat diverge on the phases that mediate this result, there is general agreement on the necessity of distinct levels of processing that must occur before a word is produced. After the concept of the intended word or message is prepared, the speaker must retrieve a concept or “lemma”, which conveys the idea and is semantically and syntactically appropriate, a process often referred to as lexical selection. Although lexical selection usually occurs within the context of a more complex message, such as a sentence or phrase, this process is critical even during single word production, in order to activate a lemma that uniquely reflects the idea or object (Levelt, 1999). Lemma selection initiates a top-down spread of activation to the phonological properties of the word (the sound-based units like phonemes and syllables), which are subsequently assembled to prepare the specific motor programs required to articulate the sounds in the correct order. Finally, the articulatory system converts this motor program into the precise movements needed for overt speech. Of primary interest in the current project is the role of a particular phonological representation, the syllable, in the phonological encoding processes following lexical selection. The phonological system is not made up of stored whole-word units ready to be retrieved and produced, but of smaller “sublexical” items, which make up the individual sounds of words. For example, the phonological landscape of the word “*speaker*” would consist of its two syllables /spi/ and /kər/, its individual phonemes like the /s/ at the onset, as well as other phonological components of various sizes distinguished by psycholinguists. A phonological system consisting of sublexical sound units instead of whole words allows for the countless combinations that form the 50-100 thousand words in the average speaker's lexicon (Levelt, 1999), and it enables the flexibility to arrange sounds in unique ways to construct novel “words” outside the lexicon.

However, the representation of sublexical units in the phonological system remains a vague construct among the major models of speech production. Despite substantive knowledge about the sound structure of language, we lack a coherent model of how phonological information is organized in a network and accessed by the speaker. Of the various linguistic units investigated to explain phonological processing of words, the syllable has probably received the most attention (Alvarez, Carreiras, & de Vega, 2000; Conrad, Grainger, & Jacobs, 2007). Syllabic constraints are useful in explaining patterns of speech errors (Cholin, Levelt, & Schiller, 2006) as well as breakdowns in production for speakers with neurological speech disorders (Aichert & Ziegler, 2004). Studies of failed production in normal speakers, i.e., tip-of-the-tongue (TOT) states, have found that speakers are often able to report the number of syllables in the word despite an inability to retrieve the actual sounds (Brown, 1991; Brown & McNeill, 1966; Burke, MacKay, Worthley, & Wade, 1991; Meyer & Bock, 1992), suggesting that speakers have metalinguistic knowledge of the syllable structure of words. Recently, psycholinguistic studies have also examined the role of syllable frequency and structure in a variety of production tasks and have revealed evidence in support of a syllabification process that occurs prior to successful articulation of the word (e.g., for Dutch: Cholin et al., 2006; Levelt & Wheeldon, 1994; for Spanish: Carreiras & Perea, 2004; Perea & Carreiras, 1998; for English: Ferrand, Segui, & Humphreys, 1997; Macizo & Van Petten, 2007; for French: Laganaro & Alario, 2006). Yet, despite the role that the syllable has played in the conceptualization of the phonological system and general agreement regarding its importance during production, there are still lingering questions concerning how the syllable is represented and used within this framework (Cholin et al., 2006; Laganaro & Alario, 2006)..

Speech Production Models

The level at which the syllable may exert its ‘privileged’ processing status differs depending on the model of speech production. The idea that whole syllables are stored and used during production was proposed first by Crompton (1981) and further developed by Levelt and colleagues (Cholin et al., 2006; Levelt, 1989; Levelt & Wheeldon, 1994; Levelt et al., 1999). At the essence of this model is the “*mental syllabary*", a repository of syllable-sized phonological units, accessed by the speaker during the motor planning stage late in the production process. Despite the fact that during normal fluent speech a person may produce two to three words (or four syllables) per second, errors tend to occur only once or twice every 1000 words (Garnham, Shillcock, Brown, Mill, & Cutler, 1981). Having access to these ready-made motor programs is thought to reduce the resource load involved with phonetic encoding and planning (Aichert & Ziegler, 2004), thereby resulting in extremely rapid and largely errorless speech.

From a limited resource perspective, it makes sense to have storage space allocated only to the syllables commonly used during speech, which is measured via syllable frequency. Syllable frequency is defined as the rate of occurrence of independent syllabic units in the words of a language (Laganaro & Alario, 2006). For example, the incidence with which the syllable /ɪm/ (e.g., the first syllable in the word *impeach*) appears within the words of a language would constitute its frequency, while the number of times it appears in the onset position is defined more specifically as its positional syllable frequency. Regularly-used syllables are among the most practiced and over-learned motor programs used for production, so these items serve as short-cuts for the articulation of the word. On the other hand, instead of being retrieved from the syllabary, rare or low frequency syllables are assembled using smaller phonological segments, such as phonemes, therefore yielding slower and more error-prone speech. It is this assumption that has been used to explain the effect of syllable frequency on various production tasks, which will be explored in greater depth when empirical evidence for syllable units in speech production is discussed.

Other models (Dell, 1986; 1988; Sevald, Dell, & Cole, 1995) conceptualize a more abstract role for phonological syllables, emerging at an earlier stage of processing than the motor planning level postulated by Levelt. Dell's more recent theoretical account of syllable processing proposes that syllable information is encoded as abstract frames in the phonological word form, instead of whole chunks ready to be strung together to form words. During phonological encoding, syllable frames contain information about the constant vowel (CV) structure of the syllable and act as placeholders into which the actual sounds can be slotted at a later stage of production. For this reason, Dell's model might argue that the word's syllable structure, not syllable frequency, would most critically impact the speed and accuracy of production, with commonly-used syllable frames resulting in facilitation. Words composed of syllables with common structures, like the consonant-vowel (CV) string of the first syllable /re/ in *research*, are faster and easier to produce compared to words beginning with uncommon syllable structures, like the (CCVC) structure of the first syllable /tres/ in *trespass*. However, given that the most frequently-used syllables would also be composed of common structures, Levelt's and Dell's models would have similar predictions regarding the influence of syllable frequency on production, despite the differences in their theoretical explanations.

The importance of syllable structure is also supported by Node Structure Theory (NST; MacKay, 1987), a model of speech production that represents linguistic units as nodes in two cooperative, connectionist networks. These networks include the content network, with nodes representing phonological entities of descending size (words, syllables, and phonemes), and the sequence network, which is responsible for controlling the order of activation of the content nodes, so that the sounds of words are produced in the correct order. In this model, syllables have their own content nodes, which are in turn connected to nodes corresponding to smaller, constituent components, such as phonemes and phones. Because multisyllabic words require the coordination of multiple syllable content nodes, NST predicts that words consisting of more than one syllable will take longer to initiate production, a prediction supported by results from picture naming latencies (Santiago, MacKay, Palma, & Rho, 2000). Although NST makes a definitive statement about the existence of individual syllable nodes in the network, as with Dell's model, it makes no explicit claim about the influence of syllable frequency on production. However, it could be surmised that frequently-used syllables would have stronger and faster spreading of activation compared to less common syllable nodes, and would therefore be faster and easier to produce, a view consistent with all three major models of speech production.

One major theoretical distinction separates Levelt's model (Figure 1-1) from both Dell's and MacKay's frameworks (Figure 1-2). Levelt's *discrete-stage* model posits that activation flows only in a feed-forward direction: lemma selection to phonological encoding to phonetic encoding to articulation. However Dell's and MacKay's models are considered *interactive activation* models in that they allow for a bidirectional flow of connectivity. During typical speech production, activation flows in the intended forward direction (from the activation of conceptual semantics to lemma selection to articulation), although activation also "feeds back" in the opposite direction, from the smaller phonological properties of words back up to their lexical and semantic representations. It is through this interactive activation that an alternative explanation for the syllable frequency effect emerges, namely that facilitation from high-frequency syllables occurs due to phonological relatedness among lexical candidates that share the same syllable node. When this common node becomes activated during the production of one of these words, all other lemmas also receive feedback excitation, and the lexical nodes achieve higher levels of activation.

Findings from a variety of speech production paradigms have suggested that phonologically similar words facilitate production, although the effect of syllable frequency is not typically explained within this context. The facilitative influence of phonological relatedness has been demonstrated in studies that present a phonological prime word (e.g. for TOT states: Abrams, Trunk, & Merril, 2007; Abrams, White, & Eitel, 2003; James & Burke, 2000; White & Abrams, 2002; for picture-word interference: Damian & Martin, 1999; Taylor & Burke, 2002) or manipulate the phonological frequency of a production target (Harley & Bown, 1998; Vitevitch, 1997; 2002; Vitevitch & Sommers, 2003). For example, many researchers have examined the effect of neighborhood density, a variable that measures the degree of phonological similarity among words (Luce & Pisoni, 1998). Specifically, a word's neighborhood density is defined as the number of words that can be created by adding, deleting, or substituting one of its phonemes. Studies investigating tip-of-the-tongue states (Harely & Bown, 1998; Vitevitch & Sommers, 2003), picture naming (Vitevitch, 2002; Vitevitch & Sommers, 2003), and speech errors (Vitevitch, 1997; 2002) have found that words with dense phonological neighborhoods were produced faster and more accurately than words with sparse neighborhoods. According to Vitevitch and Sommers, the facilitatory effect of neighborhood density on production is caused by bidirectional spreading activation between the semantic and phonological representations of words. After the lexical representation of a word form (*cat*) becomes activated, it sends activation to its constituent phonological components (/k/ /ae/ /t/). These phoneme nodes send excitation back to the lexical level, partially activating other words that share the same phonemes (e.g., cut, hat, cap, etc…), who in turn send activation back to their phonological nodes, thus increasing the activation levels of all phonological components of the initial word. Words with dense phonological neighborhoods have higher levels of activation relative to words with sparse neighborhoods because their phonological nodes continuously receive activation from the large array of words that converge on those nodes.

Like neighborhood density, syllable frequency measures the degree of similarity among words, in that high-frequency syllables are those shared by a large number of lexical items (Macizo & Van Petten, 2007). In the context of interactive activation type models, high-frequency syllables would benefit from their multiple connections with the lexical nodes in the semantic system and the high density of lemmas that share the syllable. A high-frequency syllable node is repeatedly accessed during speech and the connections between lexical nodes and the phonological network are thereby strengthened, both from the top-down activation of the phonological nodes, and the bottom-up feedback activation from the phonological nodes to the lexical level. In contrast, low frequency syllable nodes are used irregularly, causing the connection strength to diminish over time. Because of these weakened connections, low-frequency syllables are rendered more difficult to produce and more vulnerable to phonological retrieval failures. Figure 1-3 highlights the difference between high-frequency and low-frequency syllable nodes and the density of their connections to lexical nodes in the semantic system.

Conversely, phonological similarity may induce competition at lexical selection. Evidence from language perception has consistently demonstrated an inhibitory effect of phonological relatedness, showing that words with high neighborhood density are recognized more slowly and less accurately than words with sparse neighborhoods (e.g. Luce & Pisoni, 1998). Furthermore, phonological similarity among words has also been shown to interfere with production in some tasks (Sevald & Dell, 1994; Vitevitch, Armbrüster, & Chu, 2004), although facilitation is generally more likely to occur than interference. For example, in a picture naming task, Vitevitch et al. (2004) found that target pictures with high “onset density” (or the number of words that possess the same onset sound) were produced more slowly than targets with fewer same-onset neighbors. The polar effect of phonological relatedness on production and perception, and the inconsistency within production tasks, remains insufficiently explained. Why would phonologically-similar words assist in one context and compete in another? Dell and Gordon (2003) argued that the competitive environment of the task dictates whether the effect of phonological frequency will be facilitative or inhibitory. During typical speech production, words with many first syllable neighbors are produced more efficiently because the connections between the lexical- and phonological-level representations are strengthened do to the repeated activation of the syllable node. However, when phonologically similar targets serve as active competitors for selection, having a dense phonological neighborhood is detrimental because there are more items that vie for selection. The possibility that high syllable frequency will produce a competitive environment for selection will be directly tested in the current project by introducing a direct phonological “competitor” or prime word and comparing its influence on the production of high-frequency versus low-frequency syllable words.

Although the major theories agree that the syllable constitutes a fundamental component of phonological processing, psycholinguistic studies investigating the effect of syllable frequencies on production have yielded inconsistent results. The present project attempts to demonstrate the extent to which syllabic information influences production. More specifically, it addresses (1) the stage of production wherein syllable frequency is relevant, (2) whether the syllable frequency effect emerges as a result of mental “syllabary” of high-frequency syllables, or is due to phonological relatedness among lexical candidates, (3) whether high-frequency syllables facilitate or inhibit language production, and (4) how the phonological processing of syllables may be altered by aging. But first, extant evidence in favor of syllable-level processing will be reviewed.

Evidence from Speech Errors

As with many observations in the speech production literature, initial support for the syllable as a functional, self-contained structure in the processing of language came from analyses of speech errors. Although in everyday speech *slips-of-the-tongue* can occur at the whole word level (*sky in the cloud* for *cloud in the sky*), they more commonly involve smaller sound segments within a word (*dock the loor* for *lock the door*). One phenomenon that has been consistently reported is the *syllable position constraint*, the observation that segmental speech errors, such as segmental exchanges (switching a consonant or vowel between words), tend to occur at the same syllabic position within a word (Cholin et al., 2006). In other words, a person is more likely to exchange sounds between words when they are in the same syllable position, *raiting woom* for *waiting room*, rather than switching it with a sound in a different position, *been foodle* for *beef noodle*.

Similarly, MacKay (1972) reported that in blends of multisyllabic words, the two original words were significantly more likely to be broken at the boundary between syllables, rather than dividing up sounds within a syllable. Such errors are likely to fall in the category of synonymic intrusion, where the speaker accidentally combines two words of the roughly the same meaning, for example SYMBLEM for the blend of "symbol" and "emblem" (MacKay, 1972). The fact that these involuntary groupings of words involve the source words breaking down into syllabic parts ("sym" is the first syllable of "symbol", and "blem" is the second syllable of "emblem") implies that syllable units are involved in some stage of processing prior to articulation. Overall, evidence from speech error analysis has indicated that speech production requires syllabic processing of words, at least abstractly.

The syllable frequency effect during speech production

Empirical support for the role of syllables serving a functional purpose in speech production comes from a variety of experimental paradigms. The most common methodology of such studies has been to investigate the influence of syllable frequency, an effect independent of and additive to the well-established effect of whole-word frequency. The frequency with which a word is spoken and appears within a language influences the speed and accuracy of its production, a result consistently demonstrated with faster response times and fewer errors on a variety of production tasks (Goldrick & Rapp, 2007). However, the unique effect of syllable frequency on production has been a comparatively recent contribution to studies of single word production and has been met with some degree of controversy due to conflicting cross-linguistic evidence.

Studies investigating the role of syllable frequency have yielded the most consistent pattern of results in Spanish, with high-frequency first syllables facilitating production compared to words beginning with low-frequency syllables, and perhaps the most inconsistent in English, with some studies demonstrating a facilitative syllable frequency effect and other studies failing to show any influence of syllabic-level processes. Several factors have been suggested to explain why the syllable may play a more important role in the processing of Spanish words compared to English. Most importantly, Spanish has a “shallow” orthography (Conrad et al., 2007), so that the spelling of phonological syllables is almost perfectly consistent across words. On the other hand, in English, there is a large degree of variability in the mapping of graphemes to phonemes, meaning that a single phonological syllable could have multiple spellings across words, or a single orthographic syllable could share multiple pronunciations (Macizo & Van Petten, 2007). Therefore, while a “syllabary” model of high-frequency syllables might make sense for languages like Spanish, where syllable sound nodes always correspond to the same orthographic representation in words, perhaps a phonological relatedness account for syllable frequency may make more sense for languages with greater inconsistency, such as English.

The limited empirical work investigating syllable frequency in English substantiates the need for further exploration in English. Recently, Macizo and Van Petten (2007) used extant behavioral data from lexical decision and word naming for 3029 bi-syllabic English words. Similar to other languages, the authors found a facilitative effect for high-frequency syllables on naming times. However, other studies have failed to show any unique effect of syllable-level processes in English (e.g. Schiller, 1999; 2000). Thus, it appears that the syllable may serve as an important sublexical unit in all languages, although the type or level of processing influenced by syllable frequency might be language-specific or dependent on the demands of the task. Applying a variety of production methodologies to this question will help to provide a more solid framework for modeling the phonological system and unveiling the function of its constituent parts.

Tip-of-the-Tongue (TOT) States

One way to examine the structures affecting speech production is to isolate the involvement of specific sublexical units when production fails, particularly when the failure is caused by a breakdown in phonological processing, as opposed to lexical retrieval or articulation. Investigating the TOT phenomenon has provided useful insight about the role of phonology during speech production and serves as a valuable resource in understanding how phonology is represented and stored. A TOT state is defined as a temporary inability to retrieve a word, despite a persistent feeling of knowing what the intended word is (Brown & McNeill, 1966). TOT states can be elicited experimentally by presenting definitions or descriptions of uncommon words and asking participants to produce the name of the word. In this way, researchers have been able to examine factors that influence the prevalence of TOT rates as well as potential catalysts for the resolution of these words, revealing some insight into the factors critical for successful speech production

TOT research to date has neglected to investigate the potential impact of syllable frequency, despite several findings suggesting that TOT states are uniquely influenced by syllabic constraints. For example, speakers experiencing a TOT state can often report the number of syllables in the word despite not being able to retrieve the word itself (Brown, 1991; Brown & McNeill, 1966). The conditions that allow for resolution of TOT states also appear to be affected by syllabic influences. Speakers are more likely resolve a TOT state and retrieve the target word when they encounter a prime (an implicitly presented word aimed at triggering TOT resolution) that shares the first syllable of the TOT word (White & Abrams, 2002). This result appears to be exclusive to first-syllable priming; presenting a prime that shares only the first letter or first phoneme of target word has no impact on TOT resolution (Abrams et al., 2003), suggesting that the phonological processes involved in TOT states may be caused by a breakdown in the assembly of syllable-sized units. It therefore seems logical that syllable frequency might also play a role both in the rate of occurrence of TOT states (i.e., incidence) and in how often the TOT words are eventually retrieved (i.e., resolution).

This hypothesis is supported by our knowledge about the locus of this unique type of word finding failure. TOT states are thought to be caused by a defect in the phonological encoding stage of production (Burke et al., 1991; Levelt, 1989). Although the concept of the word (its lemma) is activated, causing the strong sense of knowing the word, connections to the word's phonological components are weakened, preventing the phonology of the word from being successfully encoded. High-frequency syllable nodes would have stronger and more stable connections to the lexical and semantic networks and would therefore be less likely to experience a retrieval failure like a TOT. Because individuals in a TOT states have yet to engage in motor planning processes (because the phonology of the word has not been retrieved and subsequently produced), if TOT rates are indeed influenced by the frequency of a word’s syllables, it suggests that syllable units are used at some point prior to motor planning, in accordance with the theories of Dell and MacKay, but inconsistent with a mental syllabary account.

Evidence from phonological priming suggests that the likelihood of a TOT being resolved might also be affected by the frequency of a word's first syllable. Priming the first syllable of the word facilitates production; if a person is more likely to encounter that syllable in other words, it suggests that words beginning with high-frequency first syllables are more likely to be resolved during a TOT state. Once the first syllable of the TOT word is primed, the rest of the phonological components can often be retrieved, and the word can be produced. On the other hand, if the introduction of a phonological prime word creates a situation where the first syllable node becomes activated and all lexical items that share that node compete for selection, TOT words with fewer first syllable neighbors may prove easier to resolve. Priming the TOT word's first syllable should promote TOT resolution due to the combination of bottom-up activation from phonological form of the prime word and top-down activation from the semantic representation of the TOT target word. However, once the first syllable node is activated via the phonology of the prime word, low-frequency syllable targets would have fewer lexical candidates competing for selection relative to high-frequency syllable nodes, therefore allowing TOT words with fewer first syllable neighbors to experience greater benefits from the processing of the prime word, and as a result, higher rates of resolution..

Picture Naming and Picture-Word Interference

Picture naming is a speech production methodology designed to capture the processes at every stage of production, from lemma activation to articulation. Relatively few studies, particularly in English, have used picture naming as a way of exploring the effect of syllable frequency on language production. What is striking about the production tasks most often reported in this literature (word naming and pseudo-word naming) is that they lack the demands of lexical selection and therefore skip the initial stages of production explained by the major models described previously. It seems neglectful to make global claims about the importance of syllabic units in speech production when the methods used thus far fail to capture the more natural process of production, which requires actually retrieving a word from the lexicon (rather than repeating a shown word) and activating its phonological components. Using a picture naming task will help to shed light on how syllable frequency affects the more generative process of word production used in everyday speech, while also informing about the level of processing where the syllable might exert its influence. Moreover, picture naming will be informative about the influence of syllable frequency on successful production, when the phonology of the word is effectively retrieved and encoded, in contrast to the retrieval failures that accompany TOTs.

As opposed to word naming, picture naming requires a process of selecting the appropriate lemma that corresponds to the visual percept of the picture. This process of lexical selection is thought to include a degree of competition among possible lexical candidates, and as a result, pictures of words with low name agreement (multiple possible lemmas) are named more slowly than pictures with unambiguous names (LaGrone & Spieler, 2006). As previously mentioned, the frequency with which a word is used in a language affects the speed with which it is produced, an effect confirmed by picture naming studies (Oldfield & Wingfield, 1965). Although it is clear that name agreement influences the process of lexical selection and competition, the location of the word frequency effect is less concrete (LaGrone & Spieler, 2006). Some empirical evidence suggests that the locus of the word frequency effect emerges at the phonological encoding stage. For example, low-frequency homophones that have a high-frequency homophone partner are named faster than non-homophone words of comparable frequency (Jescheniak & Levelt, 1994). This suggests that the production of the low-frequency homophone is facilitated by the activation of the phonological properties of the high-frequency homophone, and indicates that the effect of word frequency is specific to phonological encoding. However, this explanation ignores the potential contribution of the individual phonological components that are computed during encoding of the activated lemma. Perhaps the reported word frequency effect might be mediated by the frequency of its phonological segments, a prediction that was further examined in the current project.

The picture-word interference paradigm has also emerged as a useful way to isolate the effects of specific phonological and semantic properties on production. In this method, pictures are displayed with a visual or auditory prime[1] word that bears some relationship to the picture. The primes can be phonologically or semantically related to the picture and can be presented at the same time as the picture, precede, or follow the picture's presentation. Primes that are semantically related to the target picture consistently result in interference, an effect thought to be caused by competition for lexical selection. For example, a picture (*frog*) is named more slowly when accompanied by a semantically related prime word that is a competitor (*turtle*), compared with an unrelated prime (*lamp*) (Taylor & Burke, 2002). On the other hand, primes that are phonologically-related to the target facilitate picture naming (Damian & Martin, 1999; Taylor & Burke, 2002). Providing some of the phonology of the picture is thought to accelerate phonological encoding processes. The degree of phonological facilitation observed in picture-word interference studies has been unpredictable and seems to be

---

[1][1]In the picture-word interference literature, the word that is presented with the target picture is referred to as a "*distractor*" rather than a prime word because there are some circumstances that elicit interference, such as a semantically-related word presented before the picture. However, since phonologically-related words typically facilitate naming in picture-word interference tasks, it will be referred to as a prime throughout the paper to avoid confusion.

dependent on when the prime word is presented. For example, several studies have reported phonological facilitation when the prime word followed picture presentation but not when it preceded the picture (e.g. Taylor & Burke, 2002). Interestingly, the phonological primes used by Taylor and Burke only matched the target in one or two phonemes, not an entire syllable. Perhaps the stages of phonological encoding require priming of whole syllables, in order to enable access to the actual units used for production, which explains why the facilitation failed to occur when the prime was presented prior to the picture, before the target lemma was even selected. Furthermore, the effectiveness of phonological priming might also be affected by the frequency of the syllable that is shared by the target and prime word. Targets with a high-frequency initial syllable might be easier to prime due to the strength of connection between the phonological syllable node and the semantic system. Alternatively, priming the target's first syllable could result in slower responses times for pictures of words with high-frequency first syllables relative to low-frequency because of the greater number of alternate word forms that share that onset syllable, creating competition for selection.

Aging and Speech Production

Similar to studying the causes of production failures associated with speech errors and TOT states, aging has provided another useful method for investigating language processes. In the cognitive aging literature, it had been observed that while certain language abilities remain relatively stable throughout a lifespan, others suffer pronounced age-related declines (Kemper, 2006; Taylor & Burke, 2002). The greater breadth of experience grants older adults access to a larger lexicon than young adults (Kemper & Sumner, 2001; Verhaeghen, 2003), although they are more likely to have problems in producing known words (Burke et al., 2000). These increased word finding failures and TOT states among older adults can impair confidence in communicative settings and promote social withdrawal among older adults (Burke & Shafto, 2004; Hummert, Garstka, Ryan & Bonnesen, 2004; Ryan, See, Meneer & Trovato, 1994). Thus, it has become a major research goal to identify the specific breakdowns in the language system responsible for the degradation of production abilities among older adults, although the effect of syllable frequency on age-related changes to speech production remained unexplored prior to the current investigation.

Reviews of language abilities of older adults find general agreement that semantic-level processing is well preserved throughout most of late adulthood (e.g. Burke & Shafto, 2008), while retrieval of phonological information is impaired. The transmission deficit hypothesis, a theoretical derivative of NST, suggests that older adults' breakdown in phonological retrieval is caused by a weakening of connection strength among representations in the language system (e.g. MacKay & Burke, 1990). Although older adults experience a systemic decline in connectivity, the hierarchical organization of the networks makes certain links more vulnerable to transmission deficits than others. Access to lexical representations in the semantic network remains intact because multiple conceptual nodes unite on a lexical node; a problem in one of these links can easily be compensated by the other pathways. On the other hand, each lexical node has only a single connection to each of its constituent phonological nodes. Therefore, if one of these connections has become corrupted, the speaker will be unable to access the full phonological representation of the word and will be unable to produce the word even if the exact idea intended for expression is known. Thus, although the aging process causes a global weakening of connections between all nodes in the language system, the one-to-one connection between the lexical and the individual phonological nodes renders these links particular vulnerable during production, resulting in a higher incidence of word retrieval failures among older adults.

Age-related declines in phonological retrieval have been most clearly demonstrated by increased rates of TOT experiences among older adults (Burke & Shafto, 2008). Older adults report more frequent TOT states in self-reports and diary studies (e.g. Burke et al., 1991; Heine, Ober, & Shenaut, 1999) and also exhibit more TOT states when they are experimentally induced in the laboratory (e.g. Heine, Ober, & Shenaut, 1999; Vitevitch & Sommers, 2003). Compared to younger counterparts, older adults also report less phonological information about the TOT word, indicative of greater deterioration in the connections to its phonological representations (Burke et al., 1991). Conversely, although older adults experience more TOTs than their younger counterparts, they seem to experience the benefits of phonological priming to the same degree as young adults, at least through their early 70s (James & Burke, 2000; White & Abrams, 2002). Encountering the first syllable of the TOT word (embedded within another word) allows for an indirect route for its phonology to in turn be activated. This suggests that it is not the phonological nodes themselves that are damaged (or the syllabic representations) but flawed connections to these nodes that temporarily disable production.

Older adults' greater difficulty with the retrieval and production of specific words has also been demonstrated in the few aging studies conducted using picture-naming and picture-word interference paradigms. Overall, older adults are slower and less accurate (e.g. Bowles, Obler, & Albert, 1987; LaGrone & Spieler, 2006) when naming pictures and are disproportionately more susceptible to interference from a semantically-related prime word (Taylor & Burke, 2002). In contrast, older adults do appear to experience facilitation from a phonologically-related word to the same extent as young adults (Taylor & Burke, 2002). This suggests that older adults may benefit from encountering words with high-frequency first syllables during picture naming, thereby reducing age-related differences in production latencies.

The vulnerability of older adults to tasks requiring word-form retrieval suggests that syllable frequency might differentially affect young and older adults in TOT incidence and resolution, as well as picture and picture-word interference. Specifically, age differences may become particularly salient in words with low-frequency syllables, due to the additive effect of age-related weakening and infrequently-accessed phonological segments. However, such age differences may not be consistent within the older adult group. Research from a variety of language measures including TOT resolution (Abrams et al., 2007; Heine et al., 1999; White & Abrams, 2002) and vocabulary (e.g., Lindenberger & Baltes, 1997) suggests that age-related declines in language processing are most pronounced among the oldest adults. Despite these findings, studies of cognitive aging often report results from an older adult group that ranges almost 40 years, failing to consider the potential changes that occur during these years and portraying a negatively skewed picture of the cognitive abilities of all older adults. For this reason, the current project has differentiated between two groups of older adults (young-old and old-old) for both the TOT and picture-naming tasks in an attempt to provide insight into the progression of age-related changes in phonological processing.

The Current Project

The current project investigated the influence of syllable frequency within the context of four language production measures in English: TOT incidence, TOT resolution, picture naming, and picture-word interference. Previous research demonstrated that these tasks were responsive to manipulations of other phonological factors; thus, the syllable frequency effect was predicted to emerge in these contexts. Data from a variety of production methodologies were consulted to examine the degree to which syllable frequency produces a language- or task- specific mechanism versus a more global property of speech production. Furthermore, the possibility that phonological similarity facilitates production in some contexts while inhibiting production in others was examined by introducing a phonological prime word during TOT resolution and picture naming. To my knowledge, this is the first study to examine the combined effect of phonological priming and phonological frequency on production. It is also the first to examine whether syllable frequency produces different effects on young, young-old, and old-old speakers, in an attempt to inform about the source of age-related deficits in language production.

How then might syllable frequency influence phonological retrieval in older adults? One prediction is that the over-learned nature of the most frequently-used syllables would comparatively preserve older adults from phonological retrieval failures that contribute to declines in production, such as TOTs. In other words, the age groups' discrepancies should be smaller when producing words with high-frequency syllables because access to phonological representations is less degraded. In the current project, words beginning with low-frequency first syllables were predicted to produce a higher incidence of TOT states in all age groups, although the effect was expected to emerge even more so for both groups of older adults. The most pronounced effect of syllable frequency was expected for old-old adults, whose connections to phonological forms are the most degraded and vulnerable to retrieval failure.

Priming the first syllable for TOT resolution was predicted to be equally beneficial for young and young-old adults, but only for words with high-frequency first syllables. The combined effect of age-related weakening and infrequent retrieval of low-frequency first syllables (unlikely to be encountered in other words or recently produced) was expected to produce an additive effect, thereby disproportionately reducing TOT resolution rates for young-old adults compared to young adults. Old-old adults, who were unable to benefit from priming in previous studies, were predicted to show reduced priming effects for high-frequency syllables (relative to young and young-old adults) and an absence of priming for low-frequency syllables. Alternatively, if presenting a phonological prime word creates a situation where phonologically-similar words compete for selection, then priming the first syllable nodes of the TOT target word could result in lower resolution rates for words with high-frequency first syllables relative to low-frequency due to the greater number of words that share that syllable node. This effect should be more pronounced for young and young-old adults who are expected to show greater priming effects than old-old adults.

Similarly for picture naming, top-down connections to the most frequently accessed syllables should be less susceptible to age-related corrosion, and therefore age differences in naming latencies should be smaller for words beginning with high-frequency first syllables compared to low frequency syllables. All age groups will be faster for high-frequency syllable target pictures relative to low-frequency, but the difference in response times between the two frequency categories should be larger for both groups of older adults. The syllable frequency effect should be most apparent for the oldest adults, whose connections between lexical and phonological word forms are most impaired.

The extent to which phonologically-related words facilitate production will also be affected by syllable frequency. Picture and phonological prime word pairs beginning with high-frequency first syllables were predicted show a greater degree of facilitation compared to low-frequency first syllables. Young and older adults were expected to show comparable levels of facilitation for pictures and primes beginning with high-frequency first syllables. However, both groups of older adults would show decreased facilitation from phonological primes beginning with low-frequency syllables compared to young adults. Again, this reduction in phonological facilitation should be most extreme for old-old adults. However, if priming the syllable nodes of the target picture offsets the disadvantage granted to low-frequency first syllables, then faster naming times could occur for pictures of words with low-frequency first syllables because of the fewer amount of lexical candidates that share that node and compete for selection. Should this scenario emerge for primed picture naming, the advantage gained by low-frequency syllables should be greater for young and young-old adults, who show more consistent benefits from phonological priming.

Defining Syllable Frequency and Other Stimulus Characteristics

Although there are established norms for other phonological and orthographic features (i.e. Balota et al., 2002), CELEX (Baayen, Piepenbrock, & Gulikers, 1995) is the only source for syllable frequency norms in English. This database was used to find the phonological syllable boundaries and first syllable frequency for all stimulus items, and any items that were not found in the database were excluded from analysis. Each item's first syllable frequency was defined as the number of times its first syllable occurred in the onset position of the 17.9 million words in the corpus. Within each study, targets falling above the median were classified as having "high" syllable frequency and those falling below the median were considered "low" syllable frequency.

Because the current project used existing behavioral data and stimuli sets from previous studies, the unique effect of syllable frequency could not be isolated by matching high-and low-frequency targets on all other lexical dimensions. Thus, information was gathered about other phonological, lexical, and orthographic characteristics that could possibly impact the dependent measures and moderate the effect of syllable frequency. Each item's positional bigram frequency, length in letters, length in phonemes, and number of syllables was provided by the English Lexicon Project database (Balota et al., 2002), while the values for word frequency were gathered in the Francis and Kucera (1982) corpus. As previously mentioned, first syllable frequency is defined as the number of position-specific occurrences per 17.9 million. Word frequency reflects the number of times a word appeared in their corpus of 1.4 million items. Positional bigram frequency refers to the sum of all position-sensitive bigram frequencies within a word (Balota et al.,2007). A bigram is defined as a string of two letters, so the word CAT would consist of two bigrams CA and AT. However, position-sensitive bigrams only count the frequency of the two-letter sequence occurring in a specific word position, so the positional bigram frequency for CA in CAT would only include the occurrence of CA in the first two letter positions within a word. The other metrics (length in letters, length in phonemes, number of syllables) are self explanatory.

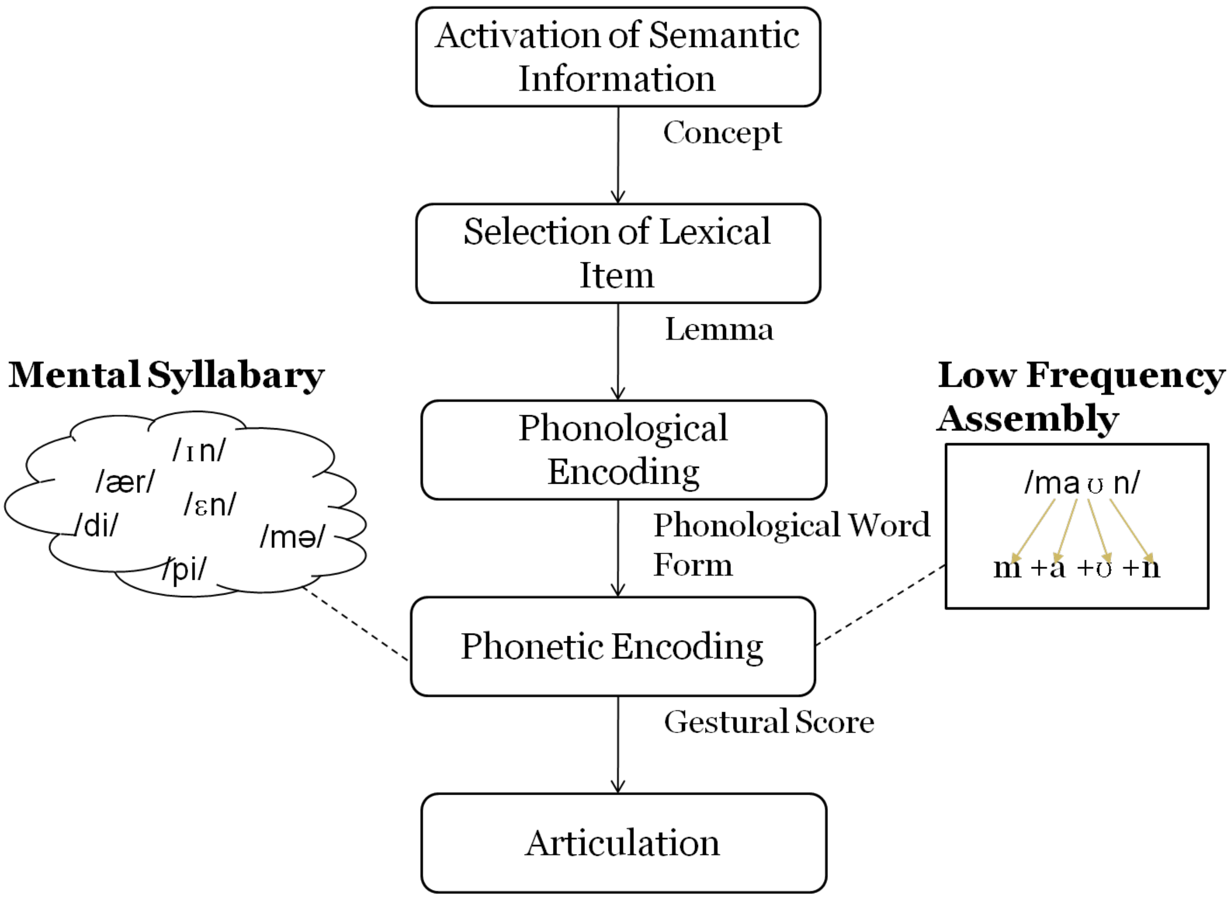


Figure 1-1. Representation of Levelt's discrete-stage model of speech production, where activation spreads in an exclusively feed-forward direction (e.g Levelt, 1989; Levelt & Wheeldon, 1994; Levelt et al., 1999).

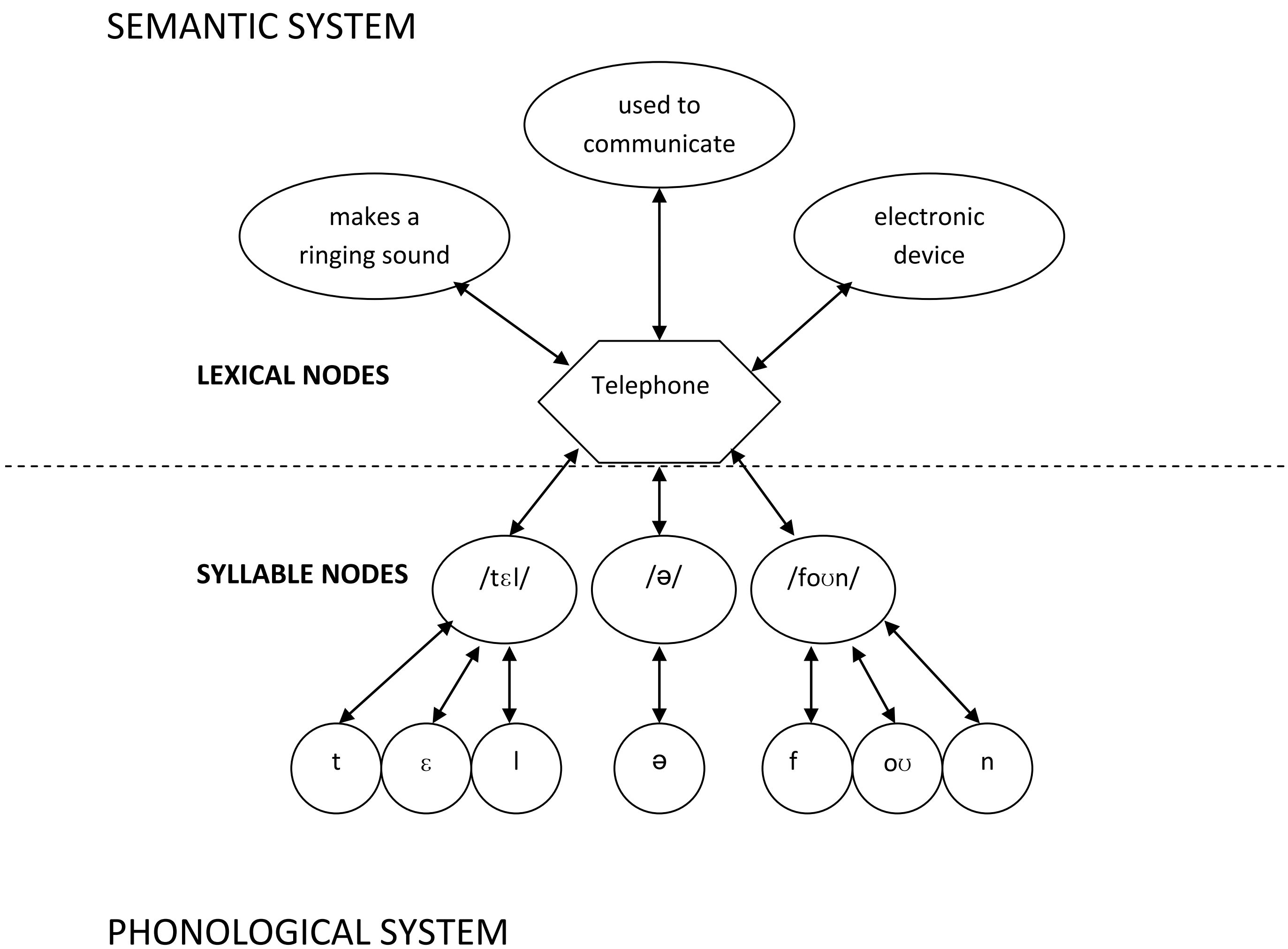


Figure 1-2. Representation of interactive activation speech production models, where connections between nodes are bidirectional.

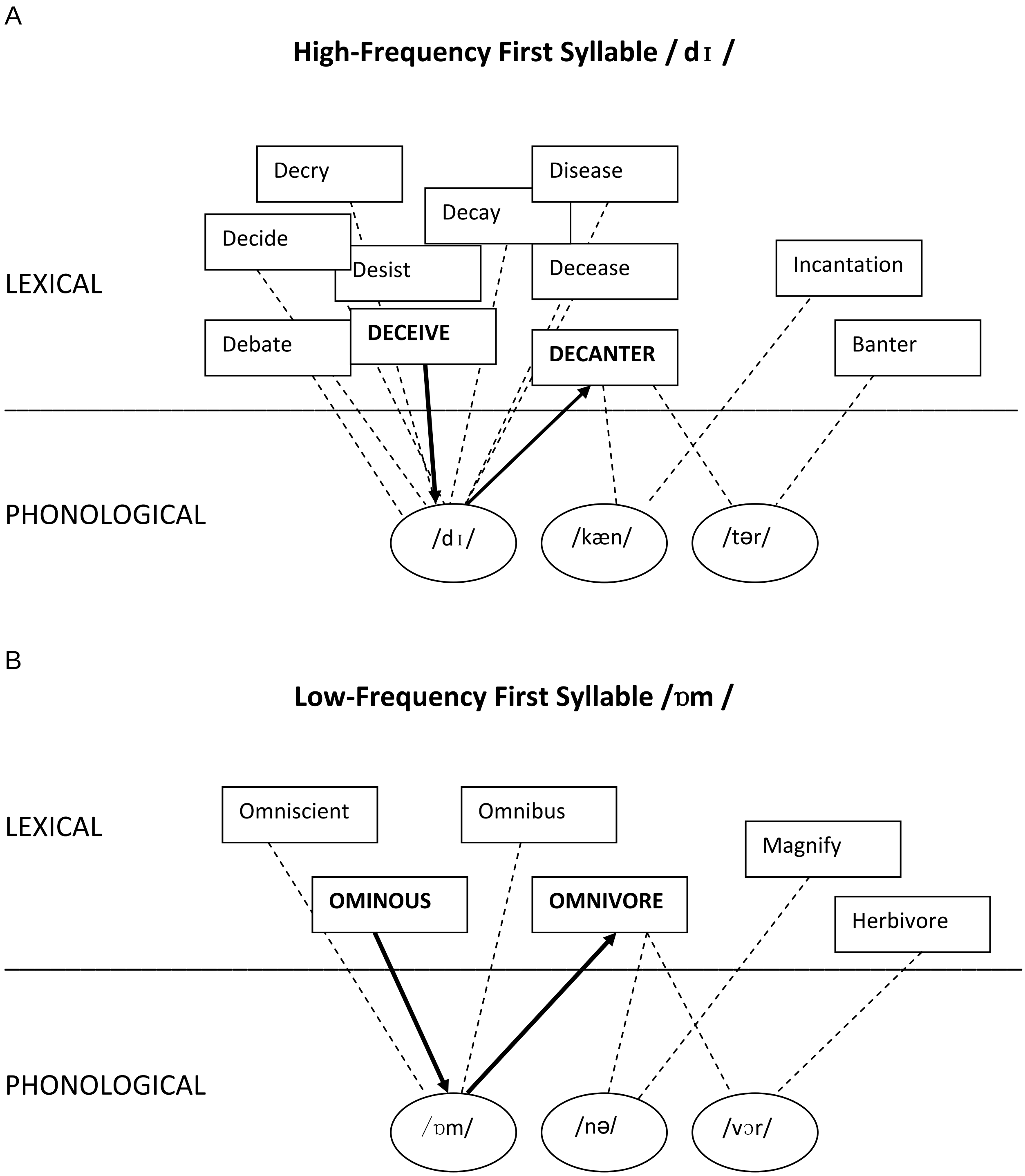


Figure 1-3. Connections between lexical-level and syllable-level representations for A.) high-frequency and B.) low-frequency syllable nodes.

CHAPTER 2
EXPERIMENT 1

Method

Data Collection and Participants

Data was compiled from three previous published studies conducted at the University of Florida Cognition and Aging Laboratory (see Abrams & Rodriguez, 2005; Abrams, Trunk, & Merrill, 2007; White & Abrams, 2002). Only the methodological information relevant for the current project is described below. Please refer to the individual studies for descriptive statistics, detailed demographics, procedural and methodological details, and the total numbers of “Know”, “Don’t Know” and “TOT” responses obtained in each study.

Across three studies (see references above), data from 179 young-adults (17-26), 110 young-old adults (60-74), and 86 old-old adults (75-89) were used to examine the influence of first syllable frequency on TOT incidence and resolution. All young adult participants were recruited from introductory psychology and cognitive psychology courses at the University of Florida and received partial course credit for participation. All older adults were recruited though the University of Florida Cognition and Aging Laboratory participant pool, a database of community-dwelling volunteers living in the Gainesville area. Older adults scored 25 or above on the Mini Mental Status Exam (Folstein, Folstein, & McHugh, 1975) to rule out the possibility of dementia and were compensated at a rate of $8 an hour. All participants were native or fluent English speakers, with normal to corrected vision, and no known diagnosis of learning disability or cognitive impairment.

Descriptive statistics for each age group are shown in Table 2-1. One-way ANOVAs were conducted to compare young, young-old and old-old adults across the following dimensions: age, education, vocabulary, forward digit-span, and backward digit-span. Young-old and old-old adults had more education and higher vocabularies than young adults (p <.001), but did not differ from each other (p > .272). Young adults had a significantly higher forward digit span than old-old adults (p < .003), was marginally higher than young-old (p < .076), and also had a higher backward digit span than both older groups (p < .048). Young-old had a marginally higher backward digit span than old-old adults (p <.066), although they did not differ in forward digit span (p >.182).

Materials

A total of 145 words were used across the three TOT studies used for analyses. However, words that were not in the CELEX database, words that elicited no TOT states in any of the experiments, and monosyllabic targets were excluded. This resulted in 130 total TOT targets used for the current study, with 65 words falling in the two syllable frequency categories. Descriptive statistics for high- and low-frequency first syllable targets are shown in Table 2-2. Independent samples t-tests were conducted to compare high- and low-frequency first syllable TOT targets across the following stimulus characteristics: first syllable frequency, word frequency, word length, bigram frequency, number of phonemes, and number of syllables. High-frequency syllable targets had higher first syllable frequency (p < .001) and also contained more syllables (p < .025). The two groups were equivalent for all other measures (p > .270).

Procedure

The TOT data were obtained using variations of the classic TOT elicitation task (e.g. Burke et al., 1991). Participants were first provided brief explanations of a TOT state, describing it as a strong feeling of knowing a word, despite an inability to retrieve it. They were then asked definition-based general knowledge questions (e.g., *What do you call a large, colored handkerchief usually worn around the neck?*) and were given the option of responding “Know”, “Don’t Know”, or “TOT”. Participants who responded with a "TOT or "Don't Know" response were then presented a list of words and were asked to read and make subjective, qualitative judgments about the words on the list. In the primed condition, one of these words was a phonological prime word that shared the same first syllable of the target, while in the unprimed condition none of the words shared any phonology with the target. For example, in Abrams and Rodriguez (2005), participants were shown a list of words and asked to make judgments about how difficult the words were to pronounce. Participants who responded that they knew the answer to the questions were asked to produce the word's name, and were then shown the word list to prevent the participants from figuring out the purpose of the word list. All of the studies included a multiple-choice recognition test at the end of the experiment for unresolved questions to ensure that those people who reported “TOT” were actually having a TOT experience and not just reporting TOT when in fact they never knew the word. Initial "TOT" responses were used for analysis only if the participant subsequently provided the correct answer to the general knowledge question on its second presentation, or correctly identified the target word on a multiple choice test.

Results

All ANOVAs were conducted using participants and items as random variables, yielding F_1 and F_2 statistics, respectively. However, in situations where the two analyses failed to produce parallel results, greater credibility was given to the participant analyses due to the items having fewer cases, more data loss, greater variability, and hence less power to detect differences.

For each experimental task, figures depict the difference in performance between low-frequency and high-frequency first syllable targets. Bars above the horizontal zero axis indicate higher TOT incidence rates and higher TOT resolution rates for low-frequency first syllable targets compared to high-frequency targets.

In the interest of brevity, only results from the analyses of variance will be reported in the results section. For the interested reader, results from a series of hierarchical regressions involving item- and participant-related variance in TOT incidence and resolution are located in Appendix A.

TOT Incidence

Table 2-3 presents the percentage of initial TOT responses, i.e., TOT incidence, produced by low-frequency and high-frequency first syllable targets for young, young-old, and old-old participants, and the difference score between high- and low-frequency first syllable targets is highlighted for each age group in Figure 2-1. TOT incidence was calculated by dividing the raw number of TOTs reported for high- and low-frequency first syllable targets by the number of questions presented in each frequency category.

A 3 (Age Group: young, young-old, and old-old) x 2 (First Syllable Frequency: high and low) repeated-measures ANOVA was conducted on the mean proportion of TOT incidence. The main effect of age group was significant, F_1 (2, 372) = 4.88, *MSE* = .01,

$p < .008$, F_2 (2, 206) = 6.93, *MSE* = .002, $p < .001$, as was the main effect of first syllable frequency, F_1 (1, 372) = 28.61, *MSE* = .003, $p < .001$, F_2 (1, 103) = 7.92, *MSE* = .008, $p < .006$. However, these main effects were qualified by a significant Age Group x First Syllable Frequency interaction, F_1 (2, 372) = 12.46, *MSE* = .003, $p < .001$, F_2 (2, 206) = 7.69, *MSE* = .002, $p < .001$. To further decompose this interaction, follow-up tests were conducted to examine the effect of syllable frequency separately for each age group. While both young-old ($p_1 < .004$; $p_2 < .043$) and old-old participants ($p_1 < .001$, $p_2 < .002$) experienced a higher proportion of TOTs for low-frequency first syllable words relative to high-frequency, young adults had equivalent rates of TOTs for high- and low-frequency targets ($p_1 > .723$; $p_2 > .678$). The age effect was also examined within each level of syllable frequency. For low-frequency target words, the pattern of age differences revealed that young (both *p*s < .001) and young-old ($p_1 < .002$, $p_2 < .001$) participants experienced fewer TOT states than old-old adults, but did not differ from one another ($p_1 > .128$; $p_2 > .863$). No age differences in TOT incidence emerged for high-frequency first syllables ($p_1 > .563$; $p_2 > .108$).

TOT Resolution

To examine the relationship between first syllable frequency and TOT resolution, an Age Group X First Syllable Frequency ANOVA was conducted on the proportion of TOTs resolved following the presentation of a phonological prime word. In this condition, participants in a TOT state were presented a prime word that shared the target's first syllable, as opposed to receiving a list of words that were both phonologically and semantically unrelated to the target. Any processes producing differences in TOT resolution as a function of first syllable frequency should effectively emerge in the primed condition, where the individual syllable units are targeted to facilitate the retrieval of the word.

Table 2-4 displays each age group's percentage of successful TOT retrievals as a function of the TOT target's first syllable frequency and prime condition (primed, unprimed), which is relevant to the analyses described below. Please refer to the top rows of means for high-frequency and low-frequency first syllable targets to compare resolution rates following a phonological prime word. The difference in resolution following a phonological prime word between low- and high-frequency syllables for each age group is also shown in Figure 2-2. The main effect of age group was significant, F_1 (2, 247) = 3.46, *MSE* = .15, $p < .033$, F_2 (2, 142) = 1.88, *MSE* = .06, $p > .156$. Young-old adults had a higher rate of TOT resolution than young ($p < .017$) and old-old adults ($p < .024$), who did not differ ($p > .864$). The effect of first syllable frequency was also significant, F_1 (1, 247) = 17.02, *MSE* = 1.83, $p < .001$; F_2 (1, 71) = 12.98, *MSE* = .094, $p < .001$, where targets beginning with low-frequency first syllables had higher resolution than targets with high-frequency first syllables. The Age Group X First Syllable Frequency interaction was not significant (both *F*s < 1).

Previous TOT research has reported age-related differences in the effectiveness of priming for TOT resolution, or the difference in resolution following a first syllable prime word compared to an unrelated word. To more directly examine potential age differences in the effect of priming, a 3 (Age Group: young, young-old, old-old) X 2 (First Syllable Frequency: high, low) X 2 (Prime Condition: primed, unprimed) repeated-measures ANOVA was initially conducted on the proportion of target words successfully retrieved following a "correct" TOT response. However, data from 104 young, 64 young-old, and 42 old-old participants were excluded from this analysis for not having at least one correct TOT response in all four conditions (2 frequency and 2 prime conditions). Given the extremely high rate of data loss (58% for young, 58% for young-old, and 49% for old-old), results from the full design will not be reported. Instead, separate Age Group X Prime Condition ANOVAs were conducted for high-frequency and low-frequency first syllable targets. Because prime condition was the only new variable in this analysis, only results relevant to the effect of a prime word relative to an unrelated word will be reported.

For high-frequency first syllable targets, the main effect of prime condition, $F_s < 1$, was not significant, nor was the Age Group X Prime Condition interaction, F_1 (2, 216) = 1.8, *MSE* = .12, p >.168, $F_2 < 1$. For low-frequency first syllable targets, the main effect of prime condition was significant, F_1 (1, 250) = 5.49, *MSE* = .13, $p < .02$; F_2 (1, 29) = 13.0, *MSE* = .044, $p < .001$, where primed targets yielded higher resolution than unprimed. The Age Group X Prime Condition interaction was significant, F_1 (2, 250) = 3.02, *MSE* = .13, $p < .051$, $F_2 < 1$. To further decompose the interaction, the effect of priming was compared separately for each age group. Priming the target word produced higher TOT resolution for young ($p < .019$) and young-old ($p < .01$) participants, while old-old adults did not exhibit priming of TOT resolution ($p > .507$). The effect of age was marginally significant for the primed ($p < .055$) and unprimed condition ($p <.054$), although the pattern of age differences differed as a function of priming. As described previously, when participants were primed, young-old adults had higher resolution than both young ($p < .032$) and old-old adults ($p < .036$), who did not differ from each other ($p > .855$). In the unprimed condition, old-old adults had higher TOT resolution than young adults ($p < .018$), while there were no differences between young and young-old participants ($p > .179$), or between the two older groups ($p > .352$). A comparison of the effect of priming for high- (top panel) and low-frequency (bottom panel) targets is shown in Figure 2-3.

Discussion

The TOT analyses confirmed the existence of a syllable frequency effect in English, with significant results emerging for TOT incidence as well as resolution. Words with low-frequency first syllables elicited more TOT states than words with high-frequency first syllables for young-old and old-old adults, consistent with predictions. However, young adults' incidence of TOT states was unaffected by syllable frequency, suggesting that the facilitative influence of high-frequency syllables may only be relevant for older adults, whose connections to phonological word forms have weakened. Furthermore, there were no age differences in TOT incidence for words beginning with high-frequency syllables, indicating that older adults' susceptibility to TOT states may be isolated to the retrieval of low-frequency phonological nodes. Contrary to incidence, high syllable frequency demonstrated an inhibitory influence on TOT resolution relative to low syllable frequency. When a phonological prime word was presented, all age groups were more likely to resolve targets with low-frequency first syllables compared to high-frequency syllable targets. These findings provide evidence for competition among phonologically-related lexical candidates when a prime is presented during a TOT state. Processing the prime word activates the first syllable of the target; when activation spreads back to the lexical level, low-frequency syllable nodes have fewer lexical items to compete for selection, and so more activation is given to the target and increases its likelihood of being resolved. Likewise, when the effect of phonological priming (or the difference in resolution following a prime word vs. and unrelated word) was examined separately for high- and low-frequency syllable targets, only low-frequency targets showed facilitation from a phonological prime word. TOT targets with high-frequency first syllables were resolved equally often following the presentation of a prime word compared to an unrelated word. Furthermore, the effect of priming was only significant for young and young-old adults. Old-old speakers were unable to benefit from the phonological prime word, even for low-frequency syllables, which suggests that connections to phonological forms grow increasingly unstable in late adulthood.

Table 2-1. Characteristics of young, young-old, and old-old participants in Experiment 1 (TOT Study)

	Age Group					
	Young		Young-Old		Old-Old	
	M	*SD*	*M*	*SD*	*M*	*SD*
Age*	19.5	1.4	68.4	3.9	79.5	3.4
Education (in years)*	13.6	1.4	16.9	3.2	16.6	2.6
Vocabulary (out of 25)*	15.3	3.0	20.5	3.1	21.0	3.0
Forward Digit Span*	7.5	1.2	7.2	1.3	6.9	1.3
Backward Digit Span*	5.7	1.2	5.4	1.4	5.0	1.2

Note: * indicates significant age group differences, p <.05.

Table 2-2. Characteristics of TOT targets with high- and low-frequency first syllables

	Syllable Frequency Category			
	High-Frequency		Low -Frequency	
	M	*SD*	*M*	*SD*
First Syllable Frequency *	3746.5	3593.4	269.8	279.8
Word Frequency	2.6	3.0	2.2	5.7
Word Length (in letters)	8.8	2.0	8.6	2.1
Positional Bigram Frequency	4383.8	2218.6	3996.4	1712.5
Number of Phonemes	7.9	1.8	7.8	2.0
Number of Syllables *	3.5	0.7	3.2	0.7

Note: * indicates significant differences between high- and low-frequency syllable targets, p<.05

Table 2-3. Young, young-old, and old-old adults' incidence of TOT states (in %) as a function of the target word's first syllable frequency

	Age Group					
	Young		Young-Old		Old-Old	
	M	*SD*	*M*	*SD*	*M*	*SD*
High-Frequency First Syllable	11.4	8.1	10.7	8.2	11.9	8.2
Low-Frequency First Syllable	11.2	8.5	12.7	7.7	16.6	9.3

Table 2-4. Mean TOT resolution rate (in %) as a function of participant age, target first syllable frequency, and prime condition

	Age Group					
	Young		Young-Old		Old-Old	
	M	*SD*	*M*	*SD*	*M*	*SD*
High-Frequency First Syllable						
Primed	25.7	34.8	31.8	37.1	24.9	32.8
Unprimed	24.3	35.2	24.3	35.2	33.0	42.6
Low-Frequency First Syllable						
Primed	35.5	37.0	49.8	40.2	35.0	32.5
Unprimed	21.4	36.1	33.2	39.9	36.9	41.5

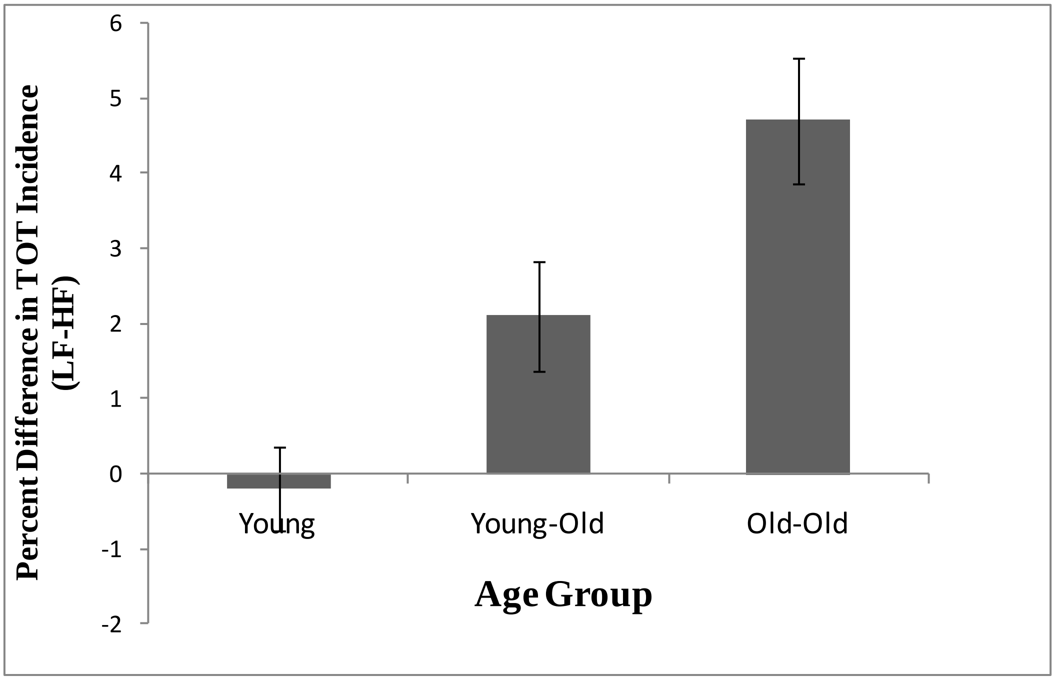


Figure 2-1. Percent difference in TOT incidence between low-frequency and high-frequency first syllable targets.

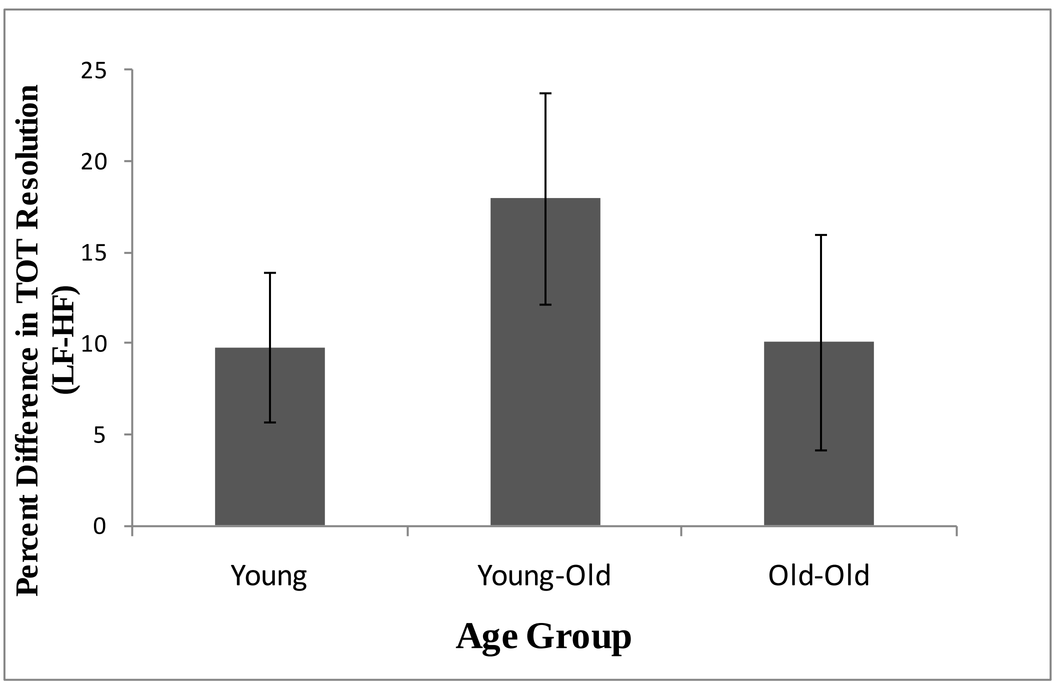
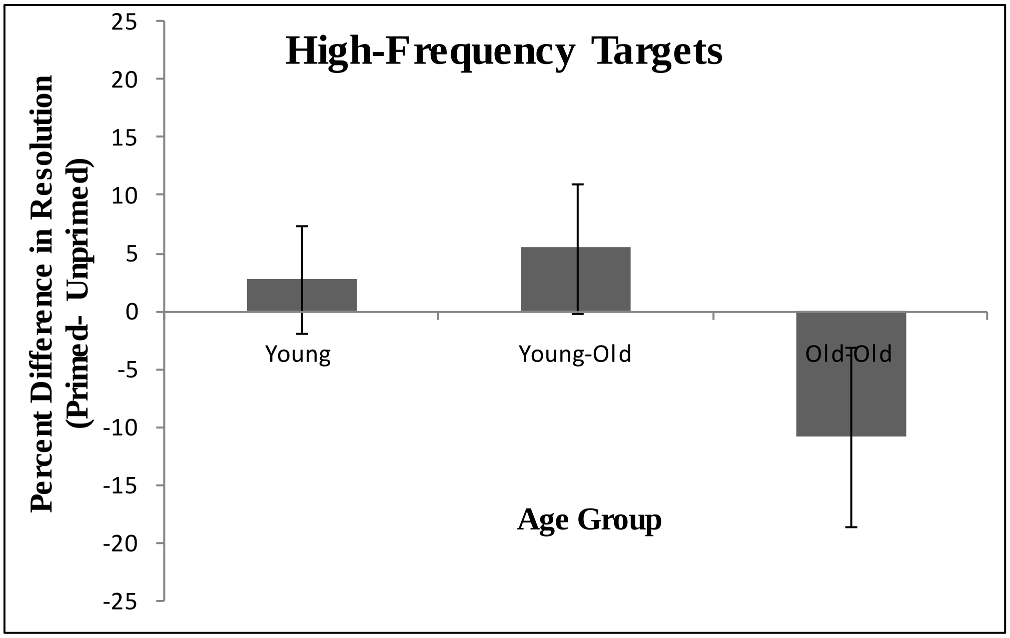


Figure 2-2. Percent difference in primed TOT resolution between low-frequency and high-frequency first syllable targets.

A



B

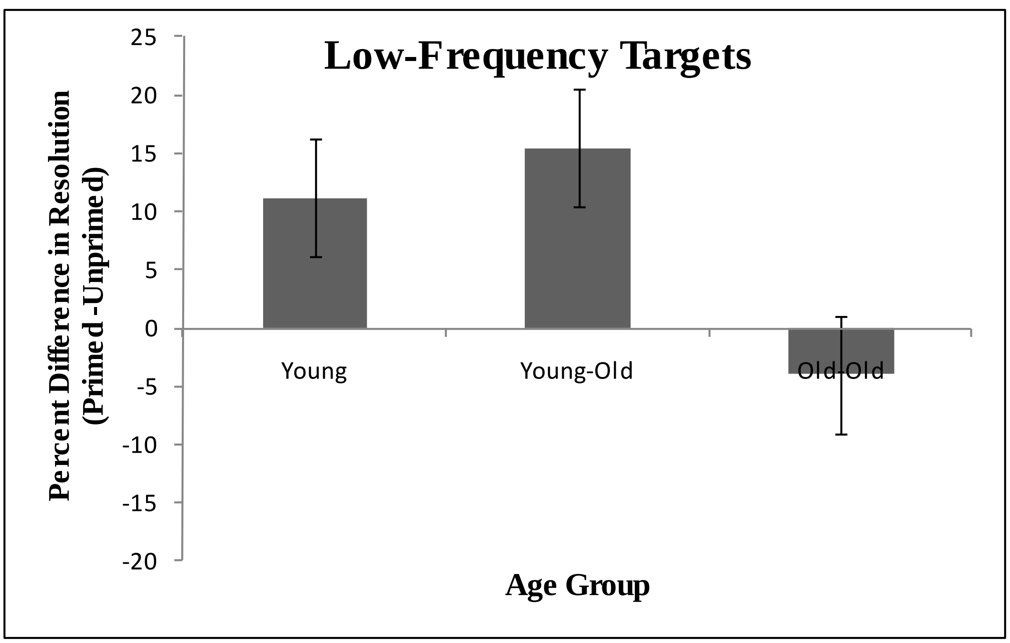


Figure 2-3. Percent difference between primed and unprimed TOT resolution for A.) high-frequency and B.) low-frequency first syllable targets.

CHAPTER 3
EXPERIMENT 2

Method

Data Collection and Participants

All picture naming data were collected in the University of Florida Cognition and Aging Laboratory, from the period of March 2008 to February 2009. Forty-eight young adults were recruited from introductory psychology courses at the University of Florida and received partial course credit for participation. All were native English speakers, with normal or corrected vision, and no history of learning disability. Forty-nine young-old adults (60-74) and 49 old-old adults (75 and older) were recruited from the Cognition and Aging Laboratory participant pool and were compensated at a rate of $8 an hour. All older adults were native speakers of English, with normal to corrected vision, and no history of stroke or neurological disorders. Older adults were given the MMSE (Folstein et al., 1975), and were required to score 25 or above in order to rule out the possibility of dementia.

Descriptive statistics within each age group are shown in Table 3-1. One-way ANOVAs were conducted to compare young, young-old and old-old adults across these dimensions. Young-old and old-old adults had more education and higher vocabularies than young adults (p <.001), but did not differ from each other (p > .109). Young adults had marginally higher forward digit span than old-old adults (p < .056), and young-old adults had higher backward digit spans than young adults (p <.048). No other comparisons were significant,(p > .109).

Materials

Pictures used in this experiment were black-and-white line drawings taken from the Peabody Picture Vocabulary test (PPVT-III; Dunn & Dunn, 1997), Boston Naming test (Kaplan, Goodglass, & Weintraub, 1983), and Microsoft Office 2007 Clip Art. All pictures depicted disyllabic or multisyllabic words that could be located in the CELEX database, resulting in 40 high-frequency and 40 low-frequency first syllable targets. Descriptive statistics for high- and low-frequency syllable targets are shown in Table 3-2. Independent samples t-tests were conducted to compare high- and low-frequency first syllable picture naming targets on all stimulus dimensions. High-frequency syllable targets had higher first syllable frequency, $p < .001$, and also contained more syllables, $p < .013$. All other measures were equal across groups, $p > .474$.

Four types of prime words were developed for each target (e.g., UNICORN): phonologically-related, same part of speech as the target (e.g., UNISON); phonologically-related, different part of speech from the target (e.g., UNITED); unrelated, same part of speech as the target (e.g., SALIVA); and unrelated, different part of speech from the target (e.g., HEROIC). However, because the primary goal of the current project was to investigate the role of sublexical influences on production, the prime words were collapsed across part of speech and only distinguished by the phonological relationship between the target and primes (i.e. whether or not the target and prime have the same first syllable). The two types of phonological primes both shared the same number of letters with the target, in order to rule out the possibility that effects were driven by orthographic similarity. Each target’s four primes were matched on syllable and letter count.

Procedure

The original experiment had a 2 x 2 x 3 design, with prime type (phonological, unrelated) and prime part of speech (same, different) as the within-participants factors and age group (young, young-old, old-old) as the between-participants variable. Older adults were first given the MMSE in order to ensure intact cognitive function. Prior to testing, all participants went through a picture naming familiarization phase, where they were shown the target pictures and asked to generate its name as quickly as possible. Participants were given feedback regarding the correctness of their response and were not able to move on to the prime task until all pictures were named correctly, i.e., using the intended name. Response latencies for pictures that were named correctly on the first viewing were recorded and saved. This data reflects single word production without distraction, and it will be used in subsequent analyses to evaluate how syllable frequency impacts the speed with which words are produced.

After all pictures were produced with the intended name, the experimenter administered the picture-word interference test. The participants were given written and verbal instructions informing that they would now see pictures with words superimposed on them and that their task was to name the picture and ignore the word. Four practice trials were administered to make sure participants were comfortable with the task. Each experimental trial began with a question mark in the center of the screen that remained until the participant pressed the space bar key. After the key press, the screen was briefly blank, followed by a small fixation point (i.e. a cross) that was in the center of the screen for 500ms to ready the participant for the presentation of the picture. The picture and prime word were displayed simultaneously and remained on screen for 3 sec, or until a key was pressed. The picture screen was followed by a 1 sec blank screen before the question mark was displayed again to set up the next trial. The 80 target pictures and 20 monosyllabic targets were presented in four blocks of 100 pictures for a total of 400 trials. Within each block, target pictures were presented at random with a filler trial occurring between every four targets. Filler trials were composed of pictures of monosyllabic words paired with an unrelated prime word, and were used in order to prevent the participants from detecting the relationship between the primes and target pictures. Pictures were paired with a different prime type in each block, and the order of prime presentations for each target was counterbalanced across participants.

Results

As with the TOT analyses, all ANOVAs were conducted using participants and items as random variables, yielding F_1 and F_2 statistics, although greater credibility is granted to the participants analyses. For traditional picture naming and primed picture naming, figures depict the difference in response times between low-frequency and high-frequency first syllable targets, and bars above zero are indicative of faster response times for pictures of words with high-frequency first syllables. The same series of hierarchical regression analyses were conducted on the picture naming data and can be found in Appendix B.

Traditional Picture Naming

Responses were included in this analysis only if the participant produced the correct target picture name without a speech or recording error, and within 3000 ms of the picture's presentation. After erroneous responses were excluded, means and SDs were computed within each age group to detect potential outliers. Response times that were $\pm$ 2.5 SD from the age group mean were removed, resulting in the loss of 3.9% of responses for young adults, 4.1% of responses for young-old adults, and 4.0% of responses for old-old adults. Data from 9 target pictures (or 11% of items) could not be used in the item analysis for failing to produce at least one correct response for each age group. These items typically depicted objects that possessed an alternate name that was not incorrect *per se*, but was not the intended target name (e.g. *merry-go-round* for *carousel*).

A 3 (Age Group: young, young-old, old-old) X 2 (First Syllable Frequency: high, low) repeated-measures ANOVA was conducted on mean response times for correctly named target pictures. Means and standard deviations from this analysis are shown in Table 3-3, while the difference between naming latencies for low- and high-frequency syllables are shown in Figure 3-1. The main effect of age group was significant, F_1 (2, 143) = 7.5, MSE = 32321.4, $p_1 < .001$, F_2 (2, 138) = 38.3, MSE = 10861.3, $p_2 < .001$, although the effect of syllable frequency was not, F_1 (1, 143) = 2.5, MSE = 4860.2, $p_1 > .117$, $F_2 <1$. The effect of age group was qualified by a significant Age Group X Syllable Frequency interaction, F_1 (2, 143) = 4.2, MSE = 4860.2, $p_1 < .017$, F_2 (2, 138) = 3.8, MSE = 10861.3, $p_2 < .024$.

Follow-up tests were conducted to investigate the effect of first syllable frequency separately for each age group. While pictures beginning with low-frequency first syllables produced longer naming latencies relative high-frequency for old-old adults, $p_1 < .004$, $p_2 > .259$, the two syllable categories were equivalent for young-old ($p_1 > .350$, $p_2 > .707$), and young adults ($p_1 > .253$, $p_2 > .469$). The effect of age group was also examined within each level of syllable frequency, revealing significant age differences in response times for both high- ($p_1 < .027$, $p_2 < .001$) and low-frequency first syllables (both *p*s < .001). The same pattern occurred for both types of syllables (but was more pronounced for low-frequency first syllables), where young adults were faster than young-old ($p_1 < .015$, $p_2 < .005$) and old-old adults, ($ps_1 < .027$, $p_2 < .01$) who did not differ from one another ($p_1 > .422$, $p2 < .007$).

Picture-Word Interference

The second phase of the picture naming experiment required the participants to name the same set of target pictures while ignoring a visually-presented prime word that either shared the same first syllable as the target picture (prime) or was unrelated to the target. As with picture naming, only responses for correctly named targets were used for the response time analyses. Furthermore, responses that were $\pm$ 2.5 SD from the age group mean were removed, resulting in the exclusion of 3.4% of correct responses for young adults, 2.6% for young-old, and 3.4% for old-old adults.

To parallel the TOT resolution analyses, a 3 (Age Group: young, young-old, old-old) X 2 (First Syllable Frequency: high, low) repeated-measures ANOVA was conducted only on response times for pictures paired with a phonological prime word, the results of which are shown in Figure 3-2. The mean responses times for pictures paired with a prime word can be found in Table 3-4, in the top row for each syllable frequency category. There were significant main effects of both syllable frequency, F_1 (1, 143) = 61.33, MSE = 505.43, $p_1 < .001$; F_2 (1, 78) = 1.47, MSE = 18642.21, $p_2 > .23$, and age group, F_1 (2, 143) = 45.61, MSE = 17535.4, $p_1 < .001$; F_2 (2, 156) = 414.17, MSE = 1702.76, $p_2 < .001$, although they were moderated by a significant two-way interaction, F_1 (1, 143) = 3.61, MSE = 505.43, $p_1 < .03$; $F_2 < 1$, $p_2 > .532$. Follow-up tests revealed that high-frequency first syllable targets produced slower response times than low-frequency targets for all age groups, but the effect was most pronounced for young adults, and least for old-old adults. For both frequency categories, young adults were faster than both young-old and old-old adults ($p < .001$), who did not differ from one another ($p > .642$), and age differences were slightly larger for low-frequency syllables.

Unlike the TOT resolution analyses, there was no data loss for any condition so the full 3 (Age Group: young, young-old, old-old) X 2 (First Syllable Frequency: high, low) X 2 (Prime Condition: prime word, unrelated) design could be explored to examine the effect of phonological priming as a function of age group and syllable frequency. Means and SDs from this analysis are shown in Table 3-4, and the difference in naming times for pictures paired with a prime word compared to an unrelated word for high- and low-frequency syllable target pictures is shown in Figure 3-3. Given that prime condition was the only novel variable in this analysis, only the results related to the effect of priming are reported. The main effect of prime condition was significant, F_1 (2, 143) = 271.25, MSE = 1594, $p_1 < .001$, F_2 (1, 71) = 129.3, MSE = 2562.8, $p_2 < .001$, but was qualified by a significant interaction with syllable frequency, F_1 (1, 143) = 22.48, MSE = 441.6, $p_1 < .001$, F_2 (1, 78) = 2.53, MSE = 1594, $p_2 > .115$. The Age Group X Prime Condition interaction was not significant, $Fs < 1$, $ps > .529$, revealing that naming times were similarly facilitated by phonological primes for all age groups. The three way interaction was also not significant, $F_1 < 1$, $p_1 > .723$, F_2 (1, 156) = 1.84, MSE = 393.27, $p_2 > .162$.

Follow-up tests were conducted to explore the Prime Condition X Syllable Frequency interaction. For both high- and low-frequency syllable targets, faster naming times occurred for prime words compared to unrelated words, $p < .001$, with a greater priming effect for low-frequency syllable targets. However, low-frequency first syllable targets produced faster naming responses relative to high-frequency targets only when paired with a prime, $p < .001$; the two frequency categories yielded equivalent naming times when the word was unrelated to the picture, $p > .217$.

Discussion

Results from the two picture naming tasks support and expand on conclusions from the TOT analyses. For traditional picture naming (without a prime word), it was predicted that all groups would be faster when naming pictures of words with high-frequency first syllables relative to low-frequency first syllables due to the regularity with which these syllable nodes are accessed. On the contrary, both young and young-old adults failed to demonstrate a significant effect of syllable frequency on naming latencies, suggesting that the frequency of sublexical components of words may not be critical during successful word production until very late adulthood. This finding is consistent with previous studies that were unable to find a unique contribution of syllabic processes on word, pseudoword, and picture naming using a masked syllable priming technique in young adults (Schiller, 1999; 2000).

However, old-old adults' naming times were influenced by syllable frequency, with faster responses emerging for targets with high-frequency first syllables compared to low-frequency syllables. The exclusive effect of syllable frequency for old-old adults provides further evidence that connections to the phonological components of words become increasingly vulnerable as we age. Old-old adults, whose paths between lexical and phonological nodes are the most degraded, are also most sensitive to manipulations of syllable frequency because greater levels of activation of phonological nodes are required to offset transmission deficits. Connections to high-frequency syllable nodes are more resistant to age-related transmission failures because they are consistently accessed during speech, even by old-old adults. This idea is supported by the lack of age differences in TOT incidence for high-frequency syllables, and the reduced age differences in naming times for high-frequency relative to low-frequency syllable target pictures. However, the combination of age-related transmission failures and infrequently accessed syllable nodes render words with low-frequency first syllables disproportionally difficult for old-old adults.

As with TOT resolution, primed picture naming resulted in inhibition from high-frequency first syllables relative to low-frequency first syllables. When a phonological prime was presented with the target picture, all age groups were faster to name pictures of words with low-frequency first syllables relative to high-frequency first syllables, although the effect was most pronounced for young adults, suggesting that they have greater difficulty selecting the target from phonologically-similar competitors. Alternatively, young adults may transfer priming activation to more lexical candidates compared to older adults. Furthermore, the degree to which naming times were facilitated by a phonological prime word (relative to an unrelated word) differed as a function of first syllable frequency; low-frequency syllable targets experienced greater phonological priming effects compared to high-frequency. However, the effectiveness of priming was comparable across age groups, indicating that phonological facilitation from a prime word, at least within the context of picture-word interference, is robust to age-related changes. These findings support the idea that presenting a prime with the same first syllable as the target induces competition among lemmas that overlap on the same first syllable node, thereby creating an advantage for words with fewer first syllable neighbors.

Table 3-1. Characteristics of young, young-old, and old-old participants in Experiment 2 (Picture Naming Study)

	Age Group					
	Young		Young-Old		Old-Old	
	M	*SD*	*M*	*SD*	*M*	*SD*
Age*	19.2	0.9	70.0	3.3	79.6	3.9
Education (in years)*	13.1	1.4	17.6	2.9	16.8	2.7
Vocabulary (out of 25)*	13.9	3.2	21.3	2.3	20.4	2.5
Forward Digit Span*	7.5	1.1	7.3	1.6	7.0	1.3
Backward Digit Span*	4.9	1.3	5.4	1.6	5.0	1.3

Note: * indicates significant age group differences, p <.05.

Table 3-2. Characteristics of target pictures with high- and low-frequency first syllables

	Syllable Frequency Category			
	High-Frequency		Low -Frequency	
	M	*SD*	*M*	*SD*
First Syllable Frequency *	2350.3	3634.9	102.8	106.5
Word Frequency	31.2	55.4	27.3	40.6
Word Length (in letters)	7.3	1.5	7.2	1.7
Positional Bigram Frequency	3738.4	1479.9	3850.4	1313.6
Number of Phonemes	6.1	1.7	5.8	1.5
Number of Syllables *	2.6	0.7	2.2	0.6

Note: * indicates significant differences between high- and low-frequency syllable targets, p<.05

Table 3-3. Mean picture naming latencies for high- and low-frequency first syllable target pictures for each age group

	Age Group					
	Young		Young-Old		Old-Old	
	M	*SD*	*M*	*SD*	*M*	*SD*
High-Frequency First Syllable	943.3	95.6	1011.2	161.7	1005.0	140.0
Low-Frequency First Syllable	927.0	103.5	1024.4	144.4	1046.7	157.3

Table 3-4. Mean picture naming latencies as a function of age group, target first syllable frequency, and prime condition

	Age Group					
	Young		Young-Old		Old-Old	
	M	*SD*	*M*	*SD*	*M*	*SD*
High-Frequency First Syllable						
Primed	825.2	65.8	973.3	112.3	977.5	97.0
Unprimed	871.8	66.2	1013.2	113.8	1029.5	109.1
Low-Frequency First Syllable						
Primed	794.9	70.1	955.1	108.6	964.1	104.3
Unprimed	857.8	69.5	1015.0	112.1	1029.3	114.4

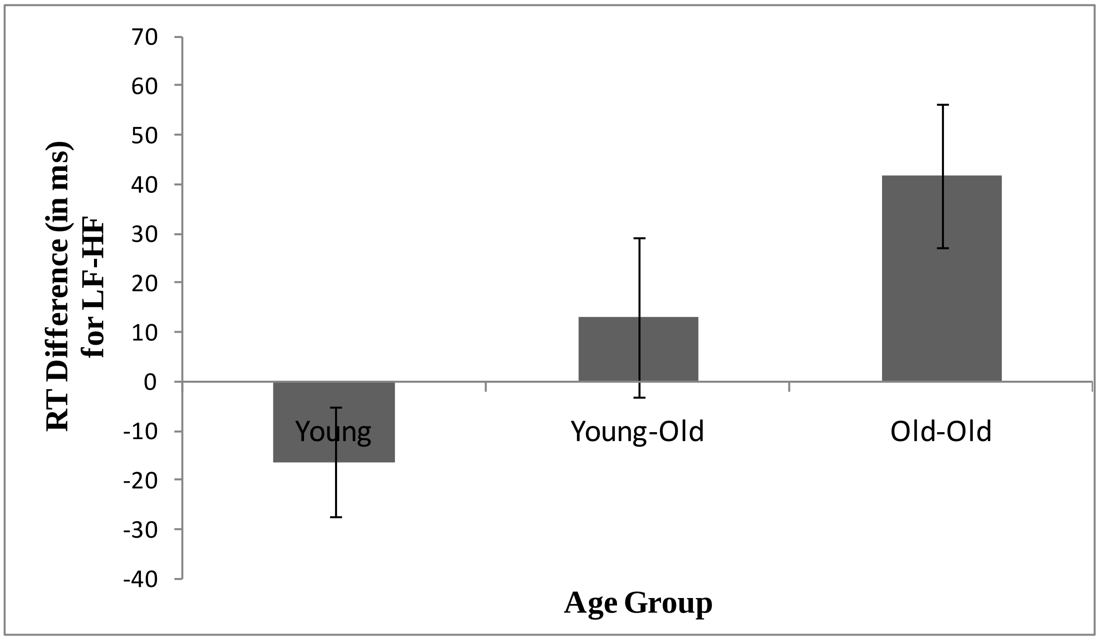


Figure 3-1. Difference in picture naming response times between low-frequency and high-frequency first syllable targets.

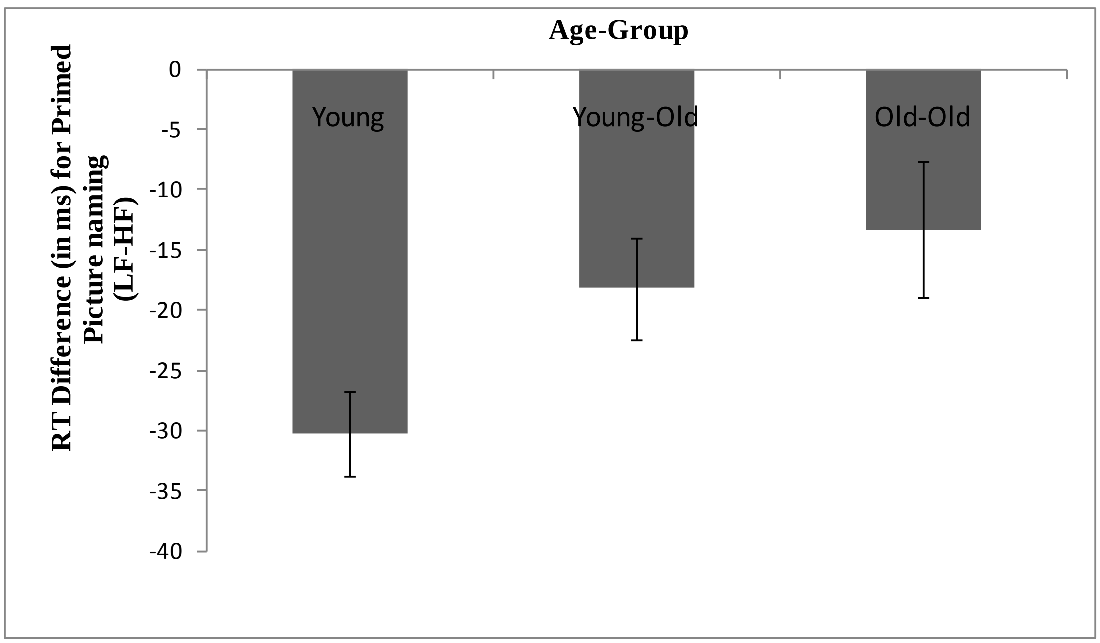


Figure 3-2. Difference in naming times between low-frequency and high-frequency syllable targets for pictures paired with a phonological prime word.

A

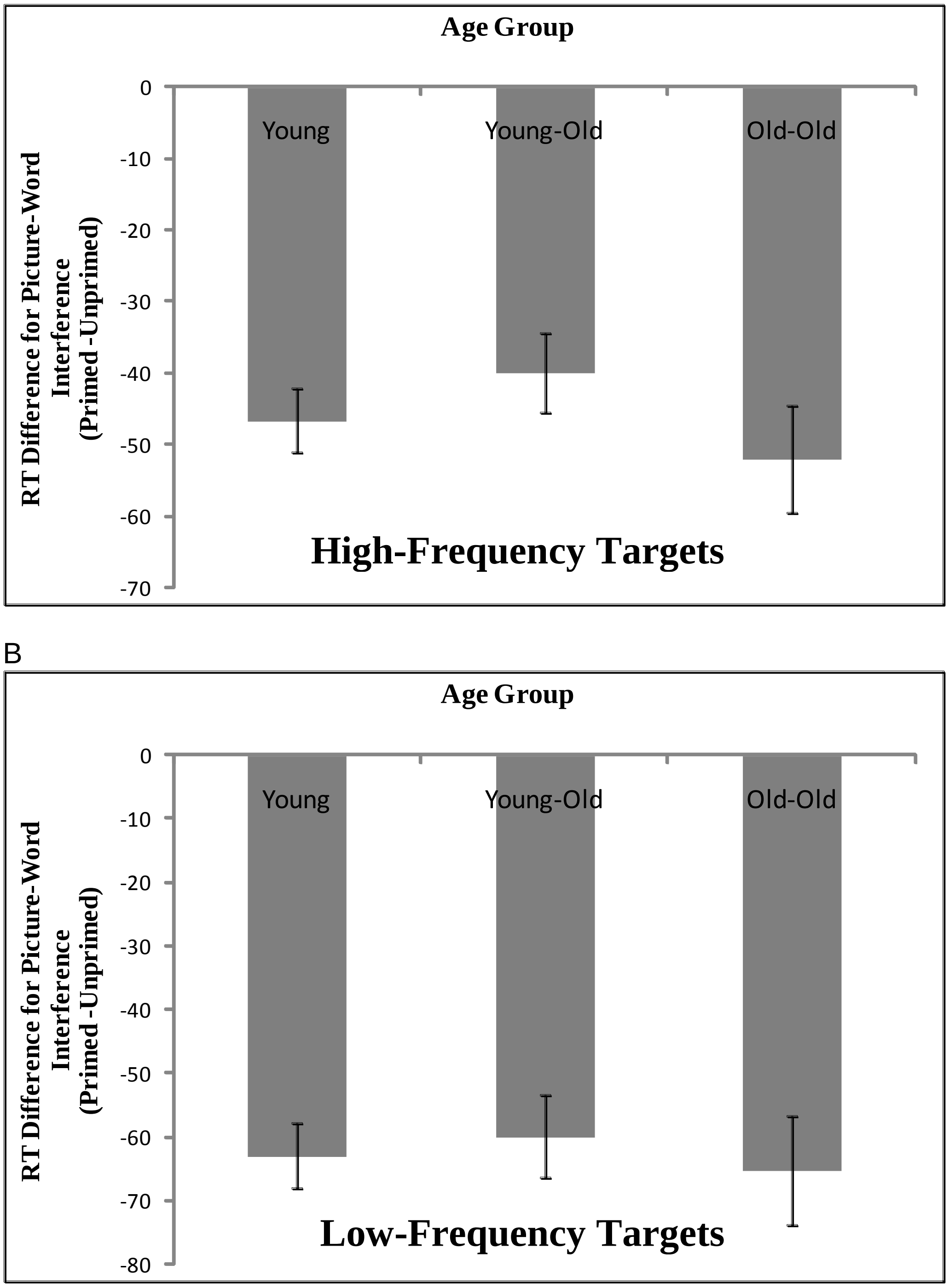


Figure 3-3. Difference in naming times between pictures paired with a prime word compared to an unrelated word for A.) high-frequency first syllable targets and B.) low-frequency syllable targets.

CHAPTER 4
GENERAL DISCUSSION

The current project produced novel findings regarding the role of syllable frequency in English speech production and unveiled valuable insight into age-related changes to phonological processes. Syllable frequency was found to have a significant effect on multiple types of speech production tasks, although the direction and magnitude effects differed as a function of the task and the speaker's age. While cross-linguistic research has shown that syllable frequency facilitates production (e.g., for Dutch: Cholin et al., 2006; Levelt & Wheeldon, 1994; for Spanish: Carreiras & Perea, 2004; Perea & Carreiras, 1998; for English: Ferrand, Segui, & Humphreys, 1997; Macizo & Van Petten, 2007; for French: Laganaro & Alario, 2006), young adults failed to demonstrate an effect of syllable frequency on TOT incidence or traditional picture naming, consistent with previous research showing no unique effect of syllable processing on the production of English words (e.g. Schiller, 1999; 2000; but see Ferrand et al., 1997; Macizo & Van Petten, 2007, for exceptions). However, syllable frequency did facilitate production for older adults, with fewer TOTs and faster picture naming latencies for targets with high-frequency first syllables relative to low-frequency. The fact that older adults alone demonstrated the facilitative influence of syllable frequency, in two different production tasks, suggests that the importance of sublexical frequency in producing language become more pronounced as we age.

Despite comparing inherently different types of tasks, syllable frequency revealed some parallels between TOT resolution and picture-word interference. When targets were produced in the context of a phonologically-related word, as was the case for primed TOT resolution and picture word interference, syllable frequency interfered with production for all age groups, with higher resolution rates and faster naming times emerging for low-frequency first syllables compared to high-frequency. The role of phonological priming in reversing the syllable frequency effect was unexpected, but suggests that phonological relatedness among lexical candidates can both facilitate and inhibit production depending on the context. Thus, syllable frequency appears to play a functional role in language production, contributing to explanations of failed phonological retrieval (TOT incidence) as well as successful word production (TOT resolution and picture naming).

For TOT incidence, it was predicted that all age groups would show a facilitative syllable frequency effect, so that more TOT states would be elicited for words with low-frequency first syllables compared to high-frequency first syllables. This prediction was based on theories that attribute TOT states to a failure to retrieve all or part of the phonological word form, despite successful activation of the semantic and possibly syntactic properties of the word (Burke et al., 1991; Levelt, 1989). In the context of Node Structure Theory (MacKay, 1987), and other connectionist models (Dell, 1986; 1988; Sevald, Dell, & Cole, 1995), high-frequency phonological segments have multiple lemmas converging on a single syllable node (see Figure 1-3). This particular node is repeatedly accessed during speech and the connections between the semantic network and the phonological network are strengthened. In contrast, low-frequency phonological forms are used irregularly, causing the connection strength to diminish over time. Because of this weakened connection, low-frequency phonological syllables are rendered more vulnerable to the phonological retrieval failures that characterize TOT states.

In support of previous research showing that TOT states are uniquely influenced by syllabic processes (Abrams et al., 2003; Brown, 1991; Brown & McNeill, 1966), syllable frequency was found to influence both TOT incidence and resolution, albeit in different ways. For both young-old and old-old adults, words with low-frequency first syllables elicited higher rates of TOT states compared to words with high-frequency first syllables, consistent with the above prediction. In contrast, young adults experienced equivalent rates of TOT states for words beginning with high-frequency and low-frequency first syllables. This suggests that connections from the semantic network to syllable-level representations are homogeneously intact for young speakers. This difference between young and older adults' sensitivity to syllable frequency in causing TOT states is not entirely surprising given our knowledge about age-related declines in connection strength between semantic and phonological representations of words. Because these links have weakened for older adults, greater strength is required to successfully activate a targeted phonological node. This property of cognitive aging coupled with the irregularity with which low-frequency syllables are retrieved produces an additive effect for older adults, and exacerbates phonological retrieval deficits for low-frequency phonological nodes. Further support for this explanation comes from the finding that age differences only occurred for words with low-frequency first syllables; high-frequency syllable targets demonstrated equivalent rates of TOT incidence for all age groups. It was predicted that older adults would experience more TOT states than young adults in all conditions, but that age differences would be more pronounced for low-frequency targets, given that older adults typically experience higher rates of TOTs both in self-report diary studies (e.g. Heine et al., 1999; Burke et al., 1991) and laboratory settings (e.g. Heine et al., 1999; Vitevitch & Sommers, 2003). The elimination of an age effect for high-frequency syllables implies that older adults' phonological retrieval problems may reflect a difficulty only in processing low-frequency sublexical items.

The differential impact of syllable frequency on young and older adults' incidence of TOT states suggests that the phonological factors that predispose speakers to TOTs may differ as a function of age, an idea that is supported by previous research demonstrating age group differences in the effects of specific linguistic characteristics on production (e.g. Vitevitch & Sommers, 2003). Vitevitch and Sommers found that the main effect of neighborhood density on TOT incidence was exclusive to young adults, while the current study found an effect of syllable frequency only for young-old and old-old adults. Neighborhood density is considered a lexical-level phonological property (Dell & Gordon, 2003), in that it reflects the number of words that holistically "sound like" the target word (Luce & Pisoni, 1998). Members of a neighborhood need only to overlap on a phoneme or two, and the similarity may exist at any position in the word. In contrast, syllable frequency requires that words converge on a single syllable node and in a specific position within the word, making this process more isolated than that of neighborhood density. This solitary connection from the semantic representation of the TOT word to its onset syllable is more vulnerable to age-related decline than more widely distributed phonological properties like neighborhood effects. In sum, the results from the current study and previous research offer the possibility that young and older adults' experience with TOT states may be caused by different mechanisms, one emerging from a lexical-level phonological property and the other from sublexical processes. However, research comparing the influence of specific phonological and lexical characteristics of words on the production abilities of young and older adults is, at present, rather limited. More work is needed to develop a more comprehensive explanation of these age-specific processes.

For TOT resolution, all age groups were predicted to show higher resolution rates for target words with high-frequency first syllables relative to low-frequency first syllables. Because speakers are more likely to encounter high-frequency syllables in other words, these nodes should be more likely to receive activation that enables retrieval of the missing phonological unit, namely the first syllable. Furthermore, connections to high-frequency syllables should be stronger than links to low-frequency first syllables, so in turn would require lower levels of activation to be retrieved. However, this account fails to accommodate the potentially competitive effects of phonological similarity. An alternative explanation is that the presence of a phonological prime word would create an environment where phonologically similar words compete with the target for selection and subsequent production, thereby allowing words with low-frequency first syllables, and fewer potential competitors, to experience higher levels of priming and resolution. Regardless of a TOT word’s first syllable frequency, the processing of a prime word creates some level of competition among lexical items that share the prime’s phonology. However, the TOT target is able to be subsequently selected and resolved due to the boost in activation of its phonology from the prime word in conjunction with the top-down activation from the TOT word’s conceptual semantic representation to the lexical-level representation. In the present study, when participants were presented with a phonological prime word, all age groups experienced higher resolution for words with low-frequency first syllables compared to high-frequency. The advantage gained by low-frequency syllables is likely due to competition among lexical candidates that share the same first syllable as the target. Figure 1-3 depicts the lexical and phonological representations of a TOT word with a high-frequency first syllable, *decanter*, and a word with a low-frequency first syllable, *omniscient*. Once a prime word with the same first syllable is introduced, *deceive* for the high-frequency target and *ominous* for the low-frequency target, both syllable nodes achieve "equal status" in terms of activation strength. However, when activation spreads back to the lexical level, the low-frequency first syllable node /ɒm/ has fewer lexical items to select from, and thus greater activation is given to the target, improving its likelihood of being retrieved.

The idea of competition among lexical candidates that share the same first syllable as the target can also explain the effects of priming on TOT resolution. Whereas it was predicted that the effectiveness of priming, or the ability of a prime word to increase resolution compared to an unrelated word, would differ as a function of the target's first syllable and the speaker's age, the pattern of results deviated from original predictions, with prime words facilitating TOT resolution only for low-frequency syllables, and only for young and young-old adults. High-frequency syllable targets demonstrated no effect of priming for any age group, suggesting that the large number of lexical items with the same onset syllable prevented the target from receiving enough activation to facilitate its retrieval. Old-old adults were unable to benefit from priming for either syllable category, which is consistent with previous research demonstrating diminished (or non-existent) phonological priming effects for the oldest old adults (Abrams et al., 2007;

White & Abrams, 2002). The inability of old-old adults to benefit from priming is indicative of more advanced deterioration between the semantic and phonological forms of words. These links may have declined to such a degree that priming can no longer offset the phonological retrieval failures that underlie TOT states. Although the syllable node becomes activated through the phonology of the prime word, as evidenced by the effectiveness of priming during picture naming for old-old adults, activation fails to spread back to the lexical form of the TOT target and increase resolution.

Together, these findings are inconsistent with a "*mental syllabary*" explanation of the syllable frequency effect (Cholin et al., 2006; Levelt, 1989; Levelt & Wheeldon, 1994; Levelt et al., 1999), which states that high-frequency first syllables are produced faster and more accurately than low-frequency first syllables due to the rapid and automatic retrieval of their motor programs. This model asserts that syllable frequency affects the motor planning stage of production, immediately prior to articulation of the selected lexical item. However, individuals in a TOT state are believed to be "caught up" during phonological encoding, a stage prior to motor planning and articulation. Thus, the mental syllabary model would be unable to account for the significant effects of syllable frequency on TOT incidence. Furthermore, it is unclear why presenting a phonological prime word would reverse the effect of syllable frequency, if the facilitative influence of syllable frequency is caused by the preexisting storage of high-frequency syllables. Overall, results from both TOT incidence and resolution are more compatible with models that attribute the syllable frequency effect to the bidirectional spread of activation among phonologically-related lexical items. The number of neighbors that share a syllable node affects the ease with which it is accessed and has the ability to facilitate production is some contexts while inhibiting production in other contexts.

Although TOTs represent a situation where phonological retrieval fails to occur successfully, the above findings were not unique to that situation and instead generalize to a task where words were successfully produced. For traditional picture naming, young and old-old adults showed the same patterns that emerged for TOT incidence. Young adults failed to demonstrate a significant effect of syllable frequency on naming latencies, suggesting that the frequency of sublexical components of words may not be critical during typical, successful word production. For old-old adults, a significant effect of syllable frequency occurred, where naming times were faster for pictures of words beginning with high-frequency first syllables compared to low-frequency syllables. In contrast, young-old adults did not show a syllable frequency effect for picture naming, whereas they did for TOT incidence. Beyond this specific finding, young-old adults behaved like young adults in some measures (e.g. TOT incidence rates, priming effects) and like old-old adults in other settings (e.g. picture naming latencies), suggesting that this group represents a heterogeneous transition period, characteristic of cognitive aging.

However, one condition that consistently produced effects of syllable frequency on production was the presentation of a phonological prime. Paralleling the results from TOT resolution, all age groups experienced faster naming times for pictures of words with low-frequency first syllables compared to high-frequency first syllables, but only when paired with a phonologically-related prime word. The same process used to explain TOT resolution also applies for primed picture naming. When the participants perceive the prime word superimposed on the picture, activation spreads from the lexical level of the prime down to its constituent phonological syllable nodes, and back up to the word form level, spreading activation to all lexical candidates that also contain these phonological components. However, once activation spreads back to the lexical level, high frequency syllables possess a larger array of items that connect to the syllable node, so the activation strength is distributed among more links. Thus, in the presence of a phonological prime, high-frequency syllables inhibit production relative to low-frequency.

This account also explains why low-frequency syllables demonstrated more pronounced priming effects than high-frequency syllables. In the context of the picture-word interference task, the bottom-up priming from the phonological form of the prime word and the top-down spread of activation from the semantic representation of the picture converge on the lexical-level representation of the target, therefore accelerating its level of activation beyond all other lexical nodes, and enabling its selection and production. Low-frequency first syllables display larger bottom-up priming effects because activation is shared between fewer lexical nodes that contain the same syllable as the prime.

CHAPTER 5
CONCLUSIONS

The current project investigated the role of first syllable frequency on speech production and age-related changes to phonological processes. Specifically, it aimed to identify (1) the stage of production, if any, where syllable frequency exerts its effects, (2) whether the influence of syllable frequency is produced by a mental syllabary or by phonological relatedness among a greater number of lexical candidates, (3) the extent to which syllable frequency facilitates or inhibits production, and (4) how the processing of phonological syllables changes as we age. First, given the significant effects of syllable frequency on TOT incidence, syllable frequency seems to affect the phonological encoding stage of production, where speakers in a TOT state are unable to retrieve the phonological representations of a lexical item. Individuals in a TOT state are unable to complete phonological encoding and have not begun the motor planning and articulatory processes used for successful word production, the stage in Levelt et al.'s model where items are retrieved from the mental syllabary. Furthermore, syllable frequency influenced the degree of phonological priming observed in TOT resolution as well as picture-word interference. As with TOT incidence, the facilitatory influence of a phonological prime word is attributed to the phonological encoding stage, where processing the prime word accelerates encoding of the target word's phonology. The influence of syllable frequency on both TOT incidence and phonological priming is in conflict with the mental syllabary account of the syllable frequency effect. While this model may explain the effects of syllable frequency observed in other languages with more consistent spelling-sound mappings such as Spanish, it is unable to accommodate for the effects of syllable frequency on older adults' incidence of TOT states or the degree of phonological priming. Furthermore, if high-frequency syllable words are produced more efficiently than low-frequency syllable words due to the automatic retrieval of the motor programs for high-frequency syllables and the online assembly of low-frequency first syllables, then it is unclear why the presentation of a prime word, that is never intended for production, would be able to reverse the effects of syllable frequency, causing words with low-frequency syllables to be produced more efficiently than words with high-frequency syllables.

Interactive activation models are better equipped to explain the paradoxical influence of syllable frequency reported in this work. The number of words that share a particular syllable node influences production due to the bidirectional spread of activation from the lexical level to the phonological representations of words. Through this mechanism, phonological relatedness among lexical candidates can both facilitate and inhibit production, depending on the situation. When links to syllable nodes are weakened due to aging or infrequent use, having a large syllable cohort is beneficial for production because all lexical items that contain that syllable receive residual activation when any item with that syllable is produced. On the other hand, when a prime word is processed, the syllable node receives activation from an external source, thus leveling the playing field between high-and low-frequency syllables. When this activation feeds back up to the lexical level, words with fewer syllable "neighbors" gain the advantage because activation is distributed among fewer items.

Finally, syllable frequency exerted differential effects on young, young-old, and old-old adults, suggesting that there may be developmental changes to the way we process words at the lexical and sublexical level. Older adults, particularly old-old adults, are more sensitive to syllable frequency effects, suggesting that the level of degradation between lexical and phonological forms is impacted by the frequency of the syllable nodes. In the absence of a prime word, young adults are unaffected by syllable frequency because links to their phonological nodes are universally unimpaired. Further research is needed to investigate whether pathological aging would exacerbate the effects of syllable frequency beyond what as observed for old-old adults, which would provide further evidence that the more pervasive the decline in connection strength between semantic and phonological word forms, the more relevant syllable frequency becomes for production.

Despite evidence of weakened connections between lexical- and phonological-level word forms, the current project also produced some positive findings about the language abilities of older adults. Young-old adults experienced a TOT incidence rate that was equivalent to young adults and actually experienced higher rates of resolution than young adults when a phonological prime word was presented. The young-old advantage in TOT resolution suggests that once the first syllable of the TOT word was activated via the phonology of the prime word, young-old adults' superior word knowledge enabled them to resolve more TOT states compared to young adults. Furthermore, young-old adults benefited from the presentation of a phonological prime word (relative to an unrelated word) to the same extent as young adults for both TOT resolution as well as picture naming. In fact, the only area wherein young-old adults were outperformed by young adults was in picture naming speed, which obviously does not represent the type of production used in daily life. Even old-old adults experienced facilitation from a phonological prime word relative to an unrelated word during the picture-word interference task, suggesting that although phonological retrieval impairments exist, they are not so pervasive that they prevent the prime word from spreading activation to the phonological and lexical representations of the target. Overall, these results highlight the significance of viewing "older adults" as a heterogeneous group that continues to develop and change well into late life, rather than assuming that all individuals over 60 are doomed to global cognitive declines.

Beyond these theoretical conclusions, results of the current study offer syllable frequency as a viable measure of phonological relatedness that can be used on multisyllabic words, while previous indices, such as neighborhood density, can only be used on monosyllabic or simple disyllabic words. More studies investigating the influence syllable frequency on production are needed to better understand the extent to which the two measures of frequency produce parallel results or capture different components of phonology. In any case, this work confirms syllable frequency as a valuable construct in models of speech production and cognitive aging. Further research will have to clarify why syllable frequency becomes more critical for production as we age and whether this information can be used to improve phonological processing in older adults.

APPENDIX A
TOT REGRESSIONS

TOT Incidence

Item Regressions

Given that orthographic, phonological, and lexical characteristics of words are often interrelated, a series of hierarchical multiple regressions were conducted to assess the *unique* contribution of first syllable frequency in explaining TOT states. In order to identify potentially redundant predictor variables, exploratory correlations were conducted among the set of identified linguistic measures. Intercorrelations between stimuli characteristics are shown in Table A-1.

An underlying assumption of regression is that no perfect collinearity exists among two or more predictor variables. Although no formal assessment of multicollinearity was conducted, standard criterion states that correlations greater than .8 suggest redundancy between predictors that could affect the model's ability to accurately assess the contribution of individual predictors (Field, 2005). Therefore, if any two predictors demonstrated correlations higher than .8, only one variable was entered into the hierarchical regression. Perhaps unsurprisingly, word length (number of letters) and number of phonemes, were found to correlate very highly with one another, $r(128) = .90$, $p < .001$. Given that both are essentially measures of length, one assessing orthographic length and the other phonological length, only number of phonemes was entered into the regression equation because it seemed more relevant to the question of interest.

Separate regressions were conducted for young, young-old, and old-old adults, with the mean proportion of TOT incidence per item serving as the outcome variable. In each of the regressions, first syllable frequency was entered as the sole predictor in the first block, while the second block also included the following item-related predictor variables: (1) word frequency, (2) positional bigram frequency, (3) number of phonemes, and (4) number of syllables. In this way, the first regression model would assess the amount of variance in TOT incidence explained by syllable frequency alone, while the second step would evaluate the extent to which the model improved with the addition of the other variables.

Standardized regression coefficients (β) and significance levels for each predictor are presented in Table A-2, along with the variance explained by each step in the model. For young adults, the first model explained less than 1% of the variance in TOT incidence (R^2 = .001, F< 1). The full model explained 3.7% of the total variance, although the change in model fit was not statistically significant (ΔR^2 = .036, p>.331), and none of the variables demonstrated a significant effect on TOT incidence (p > .239). For young-old adults, first syllable frequency emerged as a significant predictor of TOT occurrence, with the single-predictor model accounting for 5.0% of the variance in incidence, F (1,103) = 5.35, MSE= .004, p < .023. Although the full predictor model accounted for 3.3% more variance in TOT incidence, the additional variables did not significantly improve the model (ΔR^2 = .034, p > .467), and no variables other than syllable frequency had a significant effect on TOT incidence (p > .147). As expected, the relationship between syllable frequency and TOT incidence was in the negative direction, so that as first syllable frequency decreased, the incidence of TOT states increased. Such was also the case for old-old adults, where first-syllable frequency accounted for 12.5% of the variance in TOT incidence, resulting in a model that was highly significant, F (1,103) = 14.59, MSE= .005, p < .001. The full model predicted slightly more variance in TOT incidence, although the change was not significant (ΔR^2 = .019, p > .698). In sum, first syllable frequency was the only variable to predict a significant amount of variance in TOT incidence among both groups of older adults, but not young adults.

Participant Regressions

To further explore the relationship between age and TOT incidence, a separate set of hierarchical regressions were also conducted using the participants' mean TOT incidence as the dependent variable. Individual characteristics that could be argued to affect the ability to retrieve words were included in the regressions to isolate the effect of age from other potential covariates. Correlations among the participant variables are displayed in Table A-3.

Although age was found to correlate significantly with all other measures, none of the correlations were high enough to warrant concerns about multicollinearity, and all of the variables were included in the hierarchical regressions. Separate regressions were conducted on incidence rates elicited by high-frequency and low-frequency first syllable targets. The same approach was taken as the item regressions; the main variable of interest, age, was entered into the first block, with the following additional variables included in the second step: (1) education (in years), (2) vocabulary, (3) forward digit-span, and (4) backward digit-span.

Results from the participant regressions are presented in Table A-4. As expected, age was not a significant predictor of incidence for high-frequency first syllable targets. The first model predicted less than 1% of the variance in incidence, which was not significant F (1, 305) = 2.07, MSE = .007, p > .151, and including all variables did not improve model fit (ΔR^2 = .001, p > .984), nor revealed any variables that predicted TOT incidence. For low-frequency first syllable targets, participant age explained 1.4% of the variance in incidence, which was significant F (1, 305) = 4.22, MSE = .008, $p < .04$. The full-predictor model explained 3% of the variance in incidence, although the change was not significant ($\Delta R^2 = .017$, $p > .277$). In the full predictor model, backward digit span was also shown to have a significant effect on TOT incidence ($\beta = -1.4$, $p < .042$), indicating that individuals with higher backward digit spans experienced fewer TOT states. Overall, age was a significant predictor of TOT incidence, but only for targets with low-frequency first syllables.

TOT Resolution

Item Regressions

The same series of hierarchical regressions used to explore the relationship between age and first syllable frequency on TOT incidence was also conducted by items on the proportion of successful TOT resolution. Only means resulting from "primed" resolution were included in the regressions in order to parallel the primary analysis from the ANOVA.

For the item regressions, first syllable frequency was entered in the first block, and the same variables were added in the second block (word frequency, number of syllables, number of phonemes, and positional bigram frequency). Results for young, young-old, and old-old adults can be found in Table A-5. Contrary to the results from the ANOVA, first syllable frequency was not a significant predictor of TOT resolution in young adults. The single-predictor model explained only 1.8% of the variance in resolution, which was not significant, F (1, 118) = 2.09, MSE = .07, $p > .151$. However, the full predictor model was marginally significant, F (5, 118) = 2.25, MSE = .07, $p < .054$, explaining 9.1% of the variance in TOT resolution, and reflecting a marginally significant improvement over the first model ($\Delta R^2 = .073$, $p < .066$). This improvement was likely caused by the marginal effect of word frequency ($\beta = -1.67$, $p < .067$), suggesting that lower frequency words yielded higher rates of resolution for young adults. For young-old participants, first syllable frequency explained 7.7% of the variance in resolution rates, resulting in a significant single-predictor model, F (1, 82) = 6.78, MSE = .1, $p < .011$. The inclusion of the other item variables did not improve model fit, ($\Delta R^2 = .034$, $p > .577$), nor did it indicate any other variables that influence resolution. Finally, for old-old adults, first syllable frequency was not a significant predictor of TOT resolution, $F < 1$, accounting for less than 1% of the variance in resolution. The full predictor model explained approximately 9.9% of the variance in resolution, reflecting a marginally significant change in model fit ($\Delta R^2 = .097$, $p < .081$). This change was driven by the marginal effect of number of syllables ($\beta = -.3$, $p < .059$), indicating that for old-old adults, words with a higher number of syllables were more difficult to resolve. In sum, syllable frequency emerged as the most significant predictor of TOT resolution for young-old adults, while syllable frequency was less predictive for young and old-old adults, where word frequency and number of syllables respectively influenced their resolution.

Participant Regressions

To examine the influence of various participant-related variables on TOT resolution, separate hierarchical regressions were conducted on mean resolution rate for high-frequency and low-frequency first syllable targets. Again, age was entered into the first block, with years of education, vocabulary, forward digit-span, and backward digit-span added in the second block. Standardized coefficients, significance values, and the variance explained by the models are presented in Table A.6. Based on the results of the ANOVAs, where young-old adults had higher rates of resolution than young and old-old adults, the linear relationship between age and TOT resolution was not expected to be significant. However, the regressions were useful in identifying other potentially important variables for predicting TOT resolution. For high-frequency first syllable targets, age was not a significant predictor of resolution, explaining less than 1% of the variance ($R^2 = .001$, $F < 1$). Including the additional variables did not improve the model ($\Delta R^2 = .007$, $p > .809$), suggesting that the resolution of high-frequency first syllable targets was unaffected by any of the variables used in the model. For low-frequency first syllables, age was not a significant indicator of resolution ($R^2 = .001$, $F < 1$), although the full predictor model accounted for 5.4% of the variance in resolution, which was significant, F (1, 261) = 2.94, MSE = .146, $p < .013$. Furthermore, including all variables significantly improved model fit, ($R^2 = .053$, $p < .007$), a change that may have been driven by the significant positive relationship between education and TOT resolution ($\beta = .25$, $p < .001$).While none of the participant variables appeared to influence TOT resolution for high-frequency syllable targets, education emerged as a significant predictor of resolution for low-frequency targets.

Table A-1. Intercorrelations among TOT Stimuli Characteristics

Measure	1	2	3	4	5	6
1. First Syllable Frequency	--	.011	.052	.05	.068	.084
2. Word Frequency		--	-.085	-.088	-.086	-.081
3. Word Length (in letters)			--	.408**	.902**	.770**
4. Positional Bigram Frequency				--	.4**	.232**
5. Number of Phonemes					--	.777**
6. Number of Syllables						--

Notes: ** Correlation significant at the 0.01 level (2-tailed)

Table A-2. Hierarchical regression results for item variables predicting TOT incidence

	Age Group					
	Young		Young-Old		Old-Old	
Model Predictors	β	*p*	β	*p*	β	*p*
Step 1						
First Syllable Frequency	-.03	.782	-.22	.023*	-.35	.001***
Step 2						
First Syllable Frequency	-.04	.682	-.21	.03*	-.35	.001***
Word Frequency	-.11	.239	-.14	.147	-.11	.238
Bigram Frequency	.02	.836	-.07	.497	-.07	.479
Number Syllables	.09	.533	.04	.776	-.07	.59
Number Phonemes	.06	.677	-.06	.663	.08	.601

Notes: For Young R^2= .001 for Step 1, ΔR^2 = .036 for Step 2; For Young-Old R^2 = .05 for Step 1, ΔR^2 = .034 for Step 2; For old-old R^2= .125 for Step 1, ΔR^2 = .019 for Step 2
* p <.05, ** p <.01, *** p< .001

Table A-3. Intercorrelations between TOT Participant Characteristics

Measure	1	2	3	4	5
1. Age	--	.548**	.649**	-.166**	-.199**
2. Education		--	.553**	.023	.037
3. Vocabulary			--	.034	.075
4. Forward Digit Span				--	.498**
5. Backward Digit Span					--

Notes: ** Correlation significant at the 0.01 level (2-tailed)

Table A-4. Hierarchical regression results for participant variables predicting TOT incidence

	Syllable Frequency Category			
	High-Frequency		Low Frequency	
Model Predictors	β	*p*	β	*p*
Step 1				
Age	-.08	.151	.12	.041*
Step 2				
Age	-.08	.339	.11	.191
Education	.03	.623	-.06	.396
Vocabulary	-.03	.721	.03	.682
Forward Digit Span	.02	.77	.07	.305
Backward Digit Span	.01	.84	-.14	.042*

Notes: For HF R^2= .007 for Step 1, ΔR^2 = .001 for Step 2; For LF R^2 = .014 for Step 1, ΔR^2 = .017 for Step 2
* p <.05, ** p <.01, *** p< .001

Table A-5. Hierarchical regression results for item variables predicting primed TOT resolution

	Age Group					
	Young		Young-Old		Old-Old	
Model Predictors	β	*p*	β	*p*	β	*p*
Step 1						
First Syllable Frequency	-.13	.151	-.28	.011*	-.04	.701
Step 2						
First Syllable Frequency	-.11	.222	-.3	.008**	-.04	.68
Word Frequency	-.17	.067	.11	.33	-.2	.099
Number Syllables	-.12	.379	-.15	.347	-.30	.059
Number Phonemes	-.09	.549	.22	.189	.13	.45
Bigram Frequency	-.05	.588	-.16	.172	.07	.604

Notes: For Young R^2= .018 for Step 1, ΔR^2 = .073 for Step 2; For Young-Old R^2 = .077 for Step 1, ΔR^2 = .034 for Step 2; For old-old R^2= .002 for Step 1, ΔR^2 = .099 for Step 2
* p <.05, ** p <.01, *** p< .001

Table A-6. Hierarchical regression results for participant variables predicting primed TOT resolution

	Syllable Frequency Category			
	High-Frequency		Low Frequency	
Model Predictors	β	*p*	β	*p*
Step 1				
Age	-.04	.563	.04	.54
Step 2				
Age	-.04	.645	-.09	.306
Education	-.03	.705	.25	.001***
Vocabulary	-.05	.597	.02	.871
Forward Digit Span	-.002	.983	-.06	.395
Backward Digit Span	.072	.339	.04	.543

Notes: For HF R^2= .001 for Step 1, ΔR^2 = .007 for Step 2; For LF R^2 = .001 for Step 1, ΔR^2 = .053 for Step 2
* p <.05, ** p <.01, *** p< .001

APPENDIX B
PICTURE NAMING REGRESSIONS

Traditional Picture Naming

Item Regressions

The same set of item variables used in the TOT regressions was used to examine the unique effect of syllable frequency on picture naming. Correlations between the picture naming item characteristics are shown in Table B-1. As with the TOT stimuli, the correlation between the two measures of word length (number of letters and number of phonemes), r (78) = .819, p <.001, was quite high, suggesting that two variables were too similar to include both in the hierarchical regression. This resulted in a regression model with first syllable frequency entered as the only predictor in the first block, and word frequency, positional bigram frequency, number of phonemes, and number of syllables added for the second block. Separate regressions were conducted on the response times produced by young, young-old and old-old participants, and Table B-2 shows the standardized regression coefficients (β), significance levels, and variances explained by each model. One of the items (yoyo) was not found in the English Lexicon Project corpus and therefore could not be used for the regression analyses. Furthermore, some of the items failed to produce at least one correct response within an age group and were also excluded from the regression model. This resulted in an item sample size of 79 for young adults, 76 for young-old adults and 71 for old-old adults.

Because the effect of syllable frequency failed to emerge in the items ANOVA, it was not expected to be a significant predictor of response times for any of the age groups. However, the regressions were conducted in order to parallel the analyses used for the TOT stimuli and to identify other potentially important lexical characteristics for predicting picture naming performance. In fact, none of the regression models nor any of the stimuli characteristics were found to explain a significant amount of variance in naming times. For young adults, syllable frequency explained only 1.8% of the variance in response times, F (1, 78) = 1.42, MSE = 48996.6, $p > .238$, and including all predictors did not improve model fit ($\Delta R^2 = .042$, $p > .523$). Syllable frequency explained less than 1% of variance for young-old adults and old-old adults (*Fs* < 1, *ps* > .526), and including the other item variables failed to improve the model for either age group. As predicted, syllable frequency was not a significant predictor of item-related variance in response times. Furthermore, none of the stimuli characteristics demonstrated a meaningful effect on picture naming response latencies. This suggests that any effects of these variables may be too subtle to be detected by the relatively small sample size.

Participant Regressions

To examine the unique contribution of age in predicting picture naming latencies, a hierarchical regression analysis was conducted using age as the only predictor in block 1, and vocabulary, education, forward digit span, and backward digit span included in block 2. Intercorrelations between the picture naming participant characteristics are shown in Table B-3.

Separate regressions were conducted on high- and low-frequency first syllable targets to assess potential differences in the effect of participant variables as a function of syllable frequency, and the results from these regressions are shown in Table B-4. For high-frequency syllable targets, the single predictor model explained 5.0% of the variance in naming times, which was significant, F (1, 143) = 7.5, MSE = 18398.2, $p < .007$. Adding the other participant variables did not improve model fit ($\Delta R^2 = .004$, *p*>.968) nor revealed any other significant predictors of naming times. Furthermore, the unique effect of age was no longer significant in the full predictor model ($p > .16$), suggesting that the variance explained by age overlapped with one or more of the other variables in the model. For low-frequency first syllable targets, the effect of age was highly significant, $F(1, 143) = 21.4$, MSE = 18805.5, $p < .001$, accounting for 13.1% of the variance in picture naming. Including the full set of predictors did not significantly improve the model ($\Delta R^2 = .006$, $p > .92$), and only the effect of age was significant. Overall, age was a significant predictor of naming times for pictures of words with both high-frequency and low-frequency first syllables, although the effect was stronger and more stable for low-frequency syllable targets.

Primed Picture Naming

Item Regressions

For both the item and participant regressions, only naming data from the prime condition are reported. This was done in order to promote simplicity and to mirror the regressions used for TOT resolution. Separate regressions were conducted on the mean response latencies produced by the three age groups, with syllable frequency entered in the first block, followed by word frequency, bigram frequency, number of syllables, and number of phonemes added in the second block. Regression statistics from the resulting models are shown in Table B-5. For young adults, the single predictor model was not significant, $F(1, 78) = 1.98$, $MSE = 3413.26$, $p > .163$, with first syllable frequency explaining 2.5% of the variance in naming times. The full predictor model did not improve model fit ($\Delta R^2 = .48$, $p > .751$), and did not produce any significant predictors of naming times. Syllable frequency was also not a significant predictor of naming times for young-old or old-old adults, $Fs < 1$, $p > .369$, and the additional variables failed to produce a significant improvement in either model. As with the picture naming data, none of the item characteristics produced a large enough effect on naming times for primed picture naming to be detected by the regression equations.

Participant Regressions

Mean response times for high- and low-frequency targets were the outcome variables in two separate hierarchical regressions. Again age was entered as the only predictor in block 1, and vocabulary, education, forward digit span, and backward digit span were added as predictors in block 2. The results of these regressions can be found in Table B.6. For high-frequency syllable targets, the single predictor model explained 35.2% of the variance in naming times, which was significant, F (1, 143) = 77.04, MSE = 8906.45, $p < .001$. Nearly identical results emerged for low-frequency first syllable targets. The single-predictor model was highly significant, F (1, 143) = 89.67, MSE = 9248.76, $p < .001$, accounting for 38.7% of the variance in picture naming. Including the full set of predictors did not significantly improve the model ($\Delta R^2 = .002$, $p > .979$), and only the effect of age was significant. Thus, independent of the items' first syllable frequency, age emerged as a highly significant predictor of response times in the picture-word interference paradigm, and explained a larger amount of variance than for picture naming without distraction.

Table B-1. Intercorrelations for picture naming stimuli characteristics

Measure	1	2	3	4	5	6
1. First Syllable Frequency	--	-.102	.206	-.095	.299**	.407**
2. Word Frequency		--	-.174	-.014	-.237*	-.157
3. Word Length (in letters)			--	.370**	.819**	.640**
4. Positional Bigram Frequency				--	.204	.236*
5. Number of Phonemes					--	.768*
6. Number of Syllables						--

Notes: * Correlation significant at the $p < 0.05$ level, ** $p < .001$ (two-tailed)

Table B-2. Hierarchical regression results for item variables predicting picture naming response times

	Age Group					
	Young		Young-Old		Old-Old	
Model Predictors	β	p	β	p	β	p
Step 1						
First Syllable Frequency	.13	.238	.02	.878	-.08	.526
Step 2						
First Syllable Frequency	.20	.126	.11	.39	-.02	.899
Word Frequency	.09	.432	.04	.725	-.03	.838
Bigram Frequency	.19	.122	.20	.104	.16	.212
Number Syllables	-.08	.657	-.12	.524	-.13	.522
Number Phonemes	-.004	.981	-.07	.716	.03	.893

Notes: For Young R^2= .018 for Step 1, ΔR^2 = .042 for Step 2; For Young-Old R^2 = 0 for Step 1, ΔR^2 = .052 for Step 2; For old-old R^2= .006 for Step 1, ΔR^2 = .027 for Step 2
* p <.05, ** p <.01, *** p< .001

Table B-3. Intercorrelations between picture naming participant characteristics

Measure	1	2	3	4	5
1. Age	--	.595**	.751**	-.124	.105
2. Education		--	.560**	-.126	.134
3. Vocabulary			--	.021	.242**
4. Forward Digit Span				--	.518**
5. Backward Digit Span					--

Notes: ** Correlation significant at the 0.01 level (2-tailed)

Table B-4. Hierarchical regression results for participant variables predicting picture naming response times

	Syllable Frequency Category			
	High-Frequency		Low Frequency	
Model Predictors	β	p	β	p
Step 1				
Age	.22	.007**	.36	.001***
Step 2				
Age	.19	.16	.40	.002**
Education	.02	.828	.059	.562
Vocabulary	.05	.728	-.10	.452
Forward Digit Span	.05	.62	-.02	.817
Backward Digit Span	-.06	.536	.01	.954

Notes: For HF R^2= .05 for Step 1, ΔR^2 = .004 for Step 2; For LF R^2 = .131 for Step 1, ΔR^2 = .006 for Step 2
* p <.05, ** p <.01, *** p< .001

Table B-5. Hierarchical regression results for item variables predicting naming times for pictures paired with phonological primes

	Age Group					
	Young		Young-Old		Old-Old	
Model Predictors	β	*p*	β	*p*	β	*p*
Step 1						
First Syllable Frequency	.16	.163	.09	.407	.1	.369
Step 2						
First Syllable Frequency	.13	.313	.08	.536	.09	.508
Word Frequency	.15	.491	-.16	.176	.05	.806
Bigram Frequency	-.08	.536	.1	.429	.08	.553
Number Syllables	-.07	.713	.13	.483	-.13	.487
Number Phonemes	.06	.800	.21	.254	.23	.356

Notes: For Young R^2= .025 for Step 1, ΔR^2 = .023 for Step 2; For Young-Old R^2 = .009 for Step 1, ΔR^2 = .064 or Step 2; For old-old R^2= .01 for Step 1, ΔR^2 = .057 for Step 2
* p <.05, ** p <.01, *** p< .001

Table B-6. Hierarchical regression results for participant variables predicting naming times for pictures paired with phonological primes

	Syllable Frequency Category			
	High-Frequency		Low Frequency	
Model Predictors	β	p	β	p
Step 1				
Age	.593	.001***	.622	.001***
Step 2				
Age	.542	.001***	.623	.001***
Education	.038	.669	-.016	.852
Vocabulary	.049	.654	.017	.873
Forward Digit Span	.004	.949	-.002	.984
Backward Digit Span	-.067	.423	-.043	.600

Notes: For HF R^2= .352 for Step 1, ΔR^2 = .005 for Step 2; For LF R^2 = .387 for Step 1, ΔR^2 = .002 for Step 2
* p <.05, ** p <.01, *** p< .001

LIST OF REFERENCES

Abrams, L., & Rodriguez, E. (2005). Syntactic class influences phonological priming of tip-of-the-tongue resolution. *Psychonomic Bulletin & Review*, *12*(6), 1018-1023.

Abrams, L., Trunk, D. L., & Merrill, L. A. (2007). Why a superman cannot help a tsunami: Activation of grammatical class influences resolution of young and older adults' tip-of-the-tongue states. *Psychology and Aging*, *22,* 835-845.

Abrams, L., White, K. K., & Eitel, S. L. (2003). Isolating phonological components that increase tip-of-the-tongue resolution. *Memory and Cognition, 31,* 1153-1162.

Aichert, I., & Ziegler, W. (2004). Syllable frequency and syllable structure in apraxia of speech. *Brain and Language*, *88*(1), 148-159.

Álvarez, C., Carreiras, M., & de Vega, M. (2000). Syllable-frequency effect in visual word recognition: Evidence of sequential-type processing. *Psicológica*, *21*(3), 341-374.

Baayen, R.H., Piepenbrock, R., & Gulikers, L. (1995). *The CELEX lexical database* [CDROM]. Philadelphia: University of Pennsylvania, Linguistic Data Consortium.

Balota, D.A., Yap, M.J., Cortese, M.J., Hutchison, K.A., Kessler, B., Loftis, B., Neely, J.H., Nelson, D.L., Simpson, G.B., & Treiman, R. (2007). The English Lexicon Project. *Behavior Research Methods, 39*, 445-459.

Bowles, N., Obler, L., & Albert, M. (1987). Naming errors in healthy aging and dementia of the Alzheimer type. *Cortex*, *23*(3), 519-524.

Brown, A. S. (1991) A review of the tip-of-the-tongue experience. *Psychological Bulletin* 109:204–23.

Brown, R., & McNeill, D. (1966). The "tip of the tongue" phenomenon. *Journal of Verbal Learning and Verbal Behavior*, *5*, 325–337.

Burke, D. M., MacKay, D. G., Worthley, J. S., & Wade, E. (1991). On the tip of the tongue: What causes word finding failures in younger and older adults. *Journal of Memory and Language*, *30*, 542–579.

Burke, D., & Shafto, M. (2004). Aging and Language Production. *Current Directions in Psychological Science*, *13*(1), 21-24.

Burke, D. M., & Shafto, M. A. (2008). Language and aging. In F. I. M. Craik & T. A. Salthouse (Eds.), *The handbook of aging and cognition* (3rd ed., pp. 373–443). New York: Psychology Press.

Carreiras, M., & Perea, M. (2004). Naming pseudowords in Spanish: Effects of syllable frequency. *Brain and Language*, *90*(1), 393-400.

Cholin, J., Levelt, W., & Schiller, N. (2006). Effects of syllable frequency in speech production. *Cognition*, *99*(2), 205-235.

Conrad, M., Grainger, J., & Jacobs, A. (2007). Phonology as the source of syllable frequency effects in visual word recognition: Evidence from French. *Memory & Cognition*, *35*(5), 974-983.

Crompton, A. (1981). Syllables and Segments in Speech Production, *Lingusitics, 19*, 663-716.

Damian M. F., & Martin R. C. (1999). Semantic and phonological codes interact in single word production. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 25,* 345-361.

Dell, G. (1986). A spreading-activation theory of retrieval in sentence production. *Psychological Review*, *93*(3), 283-321.

Dell, G. (1988). The retrieval of phonological forms in production: Tests of predictions from a connectionist model. *Journal of Memory and Language*, *27*(2), 124-142.

Dell, GS. & Gordon, JK. (2003). Neighbors in the lexicon: Friends or foes? In N.O S Schiller & A.S. Meyer (Eds), *Phonetics and phonology in language comprehension and production:Differences and similarities.* New York: Mouten de Gruyter.

Dunn, L.M., & Dunn, L.M. (1997). Peabody Picture Vocabulary Test, Third Edition. Circle Pines, MN: American Guidance Service.

Field, A. (2005). *Discovering Statistics Using SPSS, Second Edition*. London: SAGE Publications.

Ferrand, L., Segui, J., & Humphreys, G. (1997). The syllable's role in word naming. *Memory & Cognition*, *25*(4), 458-470.

Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). Mini-mental state: A practical method for grading the state of patients for the clinician. *Journal of Psychiatric Research, 12,* 189–198.

Francis, W. N., & Kucera, H. (1982). *Frequency analysis of English usage: Lexicon and grammar.* Boston: Houghton Mifflin.

Garnham, A., Shillcock, R. C., Brown, G. D. A., Mill, A. I. D., & Cutler, A. (1981). Slips of the tongue in the London-Lund corpus of spontaneous conversation. *Linguistics*, *19*, 805–817.

Goldrick, M., & Rapp, B. (2007). Lexical and post-lexical phonological representations in spoken production. *Cognition*, *102*(2), 219-260.

Harley, T.A. & Bown, H.E. What causes a tip-of-the-tongue state? Evidence for lexical neighborhood effects in speech production. *British Journal of Psychology, 89,* 151-174.

Heine, M., Ober, B., & Shenaut, G. (1999). Naturally occurring and experimentally induced tip-of-the-tongue experiences in three adult age groups. *Psychology and Aging*, *14*(3), 445-457.

Hummert, M. L., Garstka, T. A., Ryan, E. B., & Bonnesen, J. L. (2004). The role of age stereotypes in interpersonal communication. In J. F. Nussbaum & J. Coupland (Eds.), *Handbook of communication and aging research* (2nd ed., pp. 91–114). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

James, L. E. &, Burke, D. M. (2000). Phonological priming effects on word retrieval and tip-of-the-tongue experiences in young and older adults. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *26*, 1378–1391.

Jescheniak, J., & Levelt, W. (1994). Word frequency effects in speech production: Retrieval of syntactic information and of phonological form. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *20*(4), 824-843.

Kaplan, E. F., Goodglass, H., & Weintraub, S. (1983). *The Boston Naming Test* (2nd ed.). Philadelphia: Lea & Febiger.

Kemper, S. (2006). Language in adulthood. In E. Bialystok & F. I. M. Craik (Eds.) *Lifespan cognition: Mechanisms of change* (pp. 223–238). New York: Oxford University Press.

Kemper, S., & Sumner, A. (2001). The structure of verbal abilities in young and older adults. *Psychology and Aging*, *16*, 312–322.

Laganaro, M., & Alario, F. (2006). On the locus of the syllable frequency effect in speech production. *Journal of Memory and Language*, *55*(2), 178-196.

LaGrone, S., & Spieler, D. (2006). Lexical competition and phonological encoding in young and older speakers. *Psychology and Aging*, *21*(4), 804-809.

Levelt, W. (1989). *Speaking: From intention to articulation*. Cambridge, MA US: The MIT Press.

Levelt, W. (1999). Models of word production. *Trends in Cognitive Sciences, 3*(6), 223-232.

Levelt, W., Roelofs, A., & Meyer, A. (1999). A theory of lexical access in speech production. *Behavioral and Brain Sciences*, *22*(1), 1-75.

Levelt, W., & Wheeldon, L. (1994). Do speakers have access to a mental syllabary?. *Cognition*, *50*(1), 239-269.

Lindenberger, U., & Baltes, P. (1997). Intellectual functioning in old and very old age: Cross-sectional results from the Berlin Aging Study. *Psychology and Aging*, *12*(3), 410-432.

Luce, P.A. & Pisoni, D.B. (1998). Recognizing spoken words: The neighborhood activation model. *Ear & Hearing, 19,* 1-36.

Macizo, P., & Van Petten, C. (2007). Syllable frequency in lexical decision and naming of English words. *Reading and Writing*, *20*(4), 295-331.

MacKay, D. (1972). The structure of words and syllables: Evidence from errors in speech. *Cognitive Psychology*, *3*(2), 210-227.

MacKay, D. G. (1987). *The organization of perception and action: A theory for language and other cognitive skills*. New York: Springer-Verlag.

MacKay, D. G., & Burke, D. M. (1990). Cognition and aging: A theory of new learning and the use of old connections. In T. Hess (Ed.), *Aging and cognition: Knowledge organization and utilization* (pp. 213–263). Amsterdam: North Holland.

Meyer, A., & Bock, K. (1992). The tip-of-the-tongue phenomenon: Blocking or partial activation?. *Memory & Cognition*, *20*(6), 715-726.

Oldfield, R., & Wingfield, A. (1965). Response latencies in naming objects. *The Quarterly Journal of Experimental Psychology*, *17*(4), 273-281.

Perea, M., & Carreiras, M. (1998). Effects of syllable frequency and syllable neighborhood frequency in visual word recognition. *Journal of Experimental Psychology: Human Perception and Performance*, *24*(1), 134-144.

Ryan, E. B., See, S. K., Meneer, W. B., & Trovato, D. (1994). Age-based perceptions of conversational skills among younger and older adults. In M. L. Hummert, J. M. Wiemann, & J. N. Nussbaum (Eds.), *Interpersonal communication in older adulthood* (pp. 15–39). Thousand Oaks, CA: Sage Publications.

Santiago, J., MacKay, D., Palma, A., & Rho, C. (2000). Sequential activation processes in producing words and syllables: Evidence from picture naming. *Language and Cognitive Processes*, *15*(1), 1-44.

Schiller, N. (1999). Masked syllable priming of English nouns. *Brain and Language*, *68*(1), 300-305.

Schiller, N. (2000). Single word production in English: The role of subsyllabic units during phonological encoding. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *26*(2), 512-528.

Sevald, C & Dell, G. (1994). The sequential cueing effect in speech production. *Cognition*, *53*, 91-127.

Sevald, C., Dell, G., & Cole, J. (1995). Syllable structure in speech production: Are syllables chunks or schemas?. *Journal of Memory and Language*, *34*(6), 807-820.

Taylor, J. K., & Burke, D. M. (2002). Asymmetric aging effects on semantic and phonological processes: Naming in the picture-word interference task. *Psychology and Aging*, *17*, 662–676.

Verhaeghen, P. (2003). Aging and vocabulary score: A meta-analysis. *Psychology and Aging*, *18*, 332–339.

Vitevitch, M.S. 1997. The neighborhood characteristics of malapropisms. *Language & Speech, 40,* 211-228.

Vitevitch, M.S. (2002). The influence of phonological similarity neighborhoods on speech production. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 28,* 735–747.

Vitevitch, M., Armbrüster, J., & Chu, S. (2004). Sublexical and lexical representations in speech production: Effects of phonotactic probability and onset density. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *30*, 514-529.

Vitevitch, M. S., & Sommers, M. S. (2003). The facilitative influence of phonological similarity and neighborhood frequency in speech production in younger and older adults. *Memory and Cognition*, *31*, 491–504.

White, K. K., & Abrams, L. (2002). Does priming specific syllables during tip-of-the-tongue states facilitate word retrieval in older adults? *Psychology and Aging*, *17*, 226–235.

BIOGRAPHICAL SKETCH

Meagan Farrell was born on March 15th in Fort Myers, Fl. She grew up on Fort Myers Beach with her two siblings, Liam and Caitlin, and was the salutatorian of her graduating class at Cypress Lake High School Center for the Arts in 2002. Meagan then attended Jacksonville University for two years before transferring to Appalachian State University in 2004. At both universities, she was a starting athlete on the women's soccer team, and received accolades in 2005 as a Division I Academic All-American. In May 2006 she graduated from Appalachian State *summa cum laude* with a B.A. in Psychology.

Prior to starting graduate school, Meagan worked for a year and a half as a psychometrist in southwest Florida, conducting neuropsychological testing batteries for patients with dementia, learning disability, traumatic brain injury, stroke, and a variety of other neuropsychological conditions. After receiving a College of Liberal Arts and Sciences Alumni Fellowship, she began her graduate career at UF in the fall of 2007, working closely with her research mentor Lise Abrams. Her research interests are focused on the cognitive processes enabling the production and comprehension of language in young and older adults, and the source of age-related changes to language processes. In December 2009 she will be awarded an M.S. in psychology in conjunction with her doctoral program. Upon completion of her Ph.D, Meagan plans to continue investigating age-associated changes to language and cognitive processes at an academic research institution by first obtaining a post-doctoral position followed by a professorship.